

# **San Francisco Bay Crossings Study**

## **COST REPORT**

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Prepared for  
**Metropolitan Transportation Commission**

## **COST REPORT**

### ***PURPOSE***

The purpose of this Cost Report is to describe the results of the engineering and cost analysis conducted for the San Francisco Bay Crossings Study's six alternatives. This Cost Report also includes some discussion of the methodology used to calculate alternative costs, which was previously published in the study's Cost Methodology Report.

### ***BACKGROUND***

This report represents one work product among many that have been prepared for the San Francisco Bay Crossings Study. Cost represents one of the critical criteria that will be used to evaluate the study alternatives.

The Conceptual Alternatives Report, finalized in the late summer of 2001, described a wide range of potential options for improving transbay travel. The large number and range of improvement options outlined in the Conceptual Alternatives Report were screened at a "fatal flaw" level and packaged into six alternatives for further consideration and analysis. This screening and packaging of alternatives were described in the November 19, 2001 Draft Screening and Final Definition of Alternatives Report. It should be noted that, of the many transbay travel improvement options identified in the Conceptual Alternatives Report, only a small fraction were screened out and the large majority were carried forward for further consideration.

The six alternatives carried forward for further consideration and evaluation are as follows:

- Alternative 1 – Express Bus/HOV/Operational Improvements (all corridors);
- Alternative 2 – Rail/BART Improvements in the Bay Bridge Corridor;
- Alternative 3 – San Mateo Bridge Corridor Highway Improvements;
- Alternative 4 – New Mid-Bay Bridge – I-380 to SR 238;
- Alternative 5 – Dumbarton Rail Bridge; and
- Alternative 6 – Dumbarton Bridge Corridor Highway Improvements.

### ***GENERAL COST CONSIDERATIONS***

The cost estimates which have been prepared for the 2000 Bay Crossings Study are "order-of-magnitude" construction and operating costs, which are appropriate for this type of corridor study. Cost estimates have been assembled using actual construction costs from recently constructed similar projects in the Bay Area, California and other locations as appropriate. Costs are current year estimates (2002) and no escalation has been applied, given the uncertainty as to a future year construction date.

### **Capital Cost Contingencies**

Contingency factors have been added to capital construction costs to reflect factors that are unknown at this time or not reflected in the current level of conceptual engineering. Estimate contingencies are applied to account for scope items that have not or can not be identified at this time given the degree of investigation that has been conducted as part of the current study. As different elements of alternatives can be scoped at various levels of accuracy at this time, different contingencies have been used for various alternative cost items. These contingencies are as follows:

- Crossing Items – 35%;
- Approach Items – 60%;
- Right-of-Way – 40%; and
- Rolling Stock – 10%.

The greatest level of current cost and scope uncertainty exists concerning approach items. For these items a 60 percent contingency factor has been used. This level of contingency is consistent for industry practice at this conceptual level of detail and is comparable to the Caltrans' contingency for a pre-Project Study Report (PSR) investigation. A contingency factor of 40 percent is applied to approach right-of-way as this unit can be more accurately ranged.

Additional engineering investigation has been conducted as part of this analysis relative to the “crossing” items. These improvements, included in alternatives 2, 3 and 4, are either bridges or tunnels. Since the scope of these improvements can be and has been more accurately defined at this time, a lower contingency, 35 percent, has been applied.

Finally, a contingency of 10 percent is included for rolling stock items.

### **Project Delivery**

Project delivery costs include items such as design, construction administration, construction management, design services during construction, environmental documentation, artwork, insurance, agency costs and project reserve. Based on historical experience on Bay Area and California construction projects, the following project delivery costs have been included in the study's cost estimates:

- Crossing and Approach Items – 50%; and
- Right-of-Way and Rolling Stock – 20%.

Project delivery costs are applied on construction costs adjusted to include contingencies. Contingencies are applied to account for currently unknown scope items; however, these items will need to be “delivered” as well as the known scope items.

## **Cost Ranges**

As the project team advanced through the study process, input was received relative to the cost estimate methodology, particularly as it was being applied to the major, high cost alternatives. This input suggested that the contingency and project delivery costs for the “mega projects” (defined as alternatives 2, 3 and 4) may overstate the cost of these items. Because these projects are so large, the application of historically experienced contingency and project delivery factors on projects which are not so large may not be appropriate. To account for this, cost ranges were developed for alternatives 2, 3 and 4, which include lower contingency and project delivery percentages. These “low-end” cost ranges include the following different factors:

- Crossing Project Delivery Cost – 35% (rather than 50%);
- Approach Contingency – 45% (rather than 60%); and
- Approach Project Delivery Cost – 35% (rather than 50%).

## **Conceptual Engineering**

Each alternative was reviewed at a conceptual level from an engineering and constructability standpoint, wherever possible. By reviewing each alternative in this manner, the goal was to deliver a meaningful study that would aid the MTC and other transportation and community leaders in defining new, viable and constructible transportation routes for the San Francisco Bay Area, as well as cost-effective improvements to existing transportation routes.

Key factors considered in this conceptual study included:

- Seismic design and performance; and
- Constructability issues and constraints.

## ***Seismic Design and Performance***

The idea behind seismic performance-based design is to build redundancy and seismic safety into the transbay transportation corridors. Conceptual alignments were developed considering seismic performance. For example in the case of tunnels, this meant that favorable alignments would avoid abrupt or repeated changes from soft soil to rock. In the case of bridges, the choices of favorable alignments were limited; however general mapping of the seismic risk narrowed the selection of favorable bridge types. In general, locating the crossings in the most favorable location will enhance the long-term reliability of the corridor.

## ***Constructability***

At this stage of project development only global constructability issues, such as work access and likely construction methods, were addressed with respect to type, size, and location of the fixed links considered.

## **Major Planning Level Unit Costs (Capital)**

Planning Level Estimate Unit Capital Costs are summarized in Table 0.1. They represent the project team’s opinion of probable construction costs based on professional experience and qualifications. Since the team has no control over the cost of labor, materials or equipment, services furnished by others, contractor’s methods of pricing and methods of construction, or competitive bidding or market conditions, it cannot guarantee that bid or final construction cost will not vary from the opinion of probable costs.

**Table 0.1 Summary of Major Planning Level Unit Costs (Capital)**

<b>Order of Magnitude (OM) Cost Item</b>	<b>OM Range Unit 2002 (w/o contingency &amp; project delivery)</b>	<b>Per</b>
<b><i>Major BART Item</i></b> (2 Bored Tunnels, 30-ft Diameter Bore, Space includes Gallery, Exhaust Space, Drainage Space, Route Foot costs include systems)		
2-Track Guide-Way	\$44,000 to \$66,000	R.F.
<b><i>Major Conventional Rail Item</i></b> (2 Bored Tunnels, 40-ft Diameter Bore, Space includes Gallery, Exhaust Space, Drainage Space, Route Foot costs include systems)		
2-Track Guide-Way	\$64,000 to \$90,000	R.F.
<b><i>Major Highway Bridge Items – San Mateo Widening (4- Lane)</i></b>		
Trestle over Water	\$6,600 to \$7,900	R.F.
High Bridge over Water	\$41,000 to \$49,000	R.F.
Main Span over Navigation Channel	\$135,000 to \$160,000	R.F.
<b><i>Major Highway Bridge Items – New Mid Bay Bridge</i></b> (6 – Lane + Bike Lane)		
Trestle over Water	\$12,100 to \$14,600	R.F.
High Bridge over Water	\$75,600 to \$90,800	R.F.
Main Span over Navigation Channel	\$250,000 to \$300,000	R.F.
<b><i>Major Conventional Rail Bridge Items – New Mid Bay Bridge (2-Track)</i></b>		
Trestle over Water	\$9,500 to \$11,400	R.F.
High Bridge over Water	\$48,00 to \$58,000	R.F.
Main Span over Navigation Channel	\$161,000 to \$193,000	R.F.

**Note: R.F: Route Foot**

Many of the alternatives include the purchase of transit rolling stock. The following rolling stock unit costs have been incorporated based on recent prices:

- BART Car - \$3,500,000;
- Express Bus – \$425,000; and
- Commuter Rail Train (4-Car) - \$9,400,000.

Right of way costs, including underground easements, homes and commercial structures have been priced based on recent price experience in the affected areas.

## **Operations and Maintenance Costs**

Operating and maintenance (O&M) costs estimates have been prepared for both the transit and highway components of the alternatives. Transit O&M estimates have been prepared using models that relate O&M costs to the service provided (expressed in train hours, vehicle hours, fleet requirements, for example) and the physical characteristics of the alternatives (e.g., route length, number of stations by type). Operations and maintenance estimates for highway facilities will be developed using historic estimates on similar facilities in California. A 30 percent contingency factor was applied to all annual O&M cost estimates to account for factors unknown at the current level of analysis.

Table 0.2 presents a summary of the annual O&M unit costs used in the estimates. Annual BART O&M costs have been calculated using the specific O&M model developed for BART by Manuel Padron & Associates.

**Table 0.2 Summary of Major Operational and Maintenance Unit Costs**

<b>Operational &amp; Maintenance Cost Item</b>	<b>Annual Cost</b>	<b>Per</b>	<b>Data Source</b>
New Highway Lane	\$10,000	Lane Mile	Caltrans, Pavement Management Information Branch
Express Bus	\$90	Hour	AC Transit Experience
Commuter Rail (Vehicles)	\$50	Train Mile	Caltrain Experience
Commuter Rail (Track)	\$15,000	Track Mile	Caltrain Experience
Median Barrier	\$500,000	Year	Caltrans, San Diego-Coronado Bridge
New Bridge	\$100,000	Lane Mile	MTC, Bridge Operations
Toll Crossing	\$0.265	Vehicle Crossing	MTC, Bridge Operations

Two O&M figures have been developed and are reported for each alternative. The first is an annual O&M cost. The second is a twenty year net O&M cost which assumes farebox recovery for the transit alternatives. The assumed farebox recovery ratios are as follows, based on the historical experience of other similar operators:

- BART – Farebox Recovery = 58%;
- Express Bus – Farebox Recovery = 50%; and
- Commuter Rail – Farebox Recovery = 38%.

## **Exclusions**

For this preliminary calculation of conceptual costs, certain items will be specifically excluded from the order of magnitude estimates. The major exclusions are:

- Financing, bonding and interest during construction;

- Mitigation Costs;
- Utility agency fees and charges; and
- Start-up costs for new revenue service (i.e. advertising, etc.).

## ***ALTERNATIVE 1: EXPRESS BUS, HOV, AND OPERATIONAL IMPROVEMENTS FOR ALL CORRIDORS***

### **Conceptual Engineering/Definition**

#### ***Express Bus***

Alternative 1 assumes Express Bus service expansions in the Bay Bridge, San Mateo Bridge and Dumbarton Bridge Corridors. These service plan assumptions are detailed in Appendix 1A. In summary, Alternative 1 proposes an increase in peak hour trips from 96 to 158 in the Bay Bridge Corridor, from 0 to 10 in the San Mateo Bridge Corridor and from four to 10 in the Dumbarton Bridge Corridor.

#### ***BART Services Expansion***

BART operating statistics were estimated with a model developed by Manuel Padron & Associates and calibrated to actual FY 2001 BART statistics. A memorandum describing this analysis is attached in Appendix 1B. Future operating plans assume the BART extension to San Jose and service to SFO/Millbrae. All operating plans assume a basic 12-minute peak and midday headway on each route (Red, Blue, Green, etc.) with supplemental service (i.e., rush hour trains) added where needed. The 12-minute headway is consistent with current BART service patterns and with long-range service assumptions in the MTC travel demand model.

Alternative 1 assumes 30 trains/hour through the existing tube in the peak hour. The operating plan assumes 12-minute headways on the four lines crossing the Bay (i.e., 20 trains/hour), with an additional 9 trains/hour from the West Pittsburgh line plus one train/hour from Fremont. Alternative 1 requires 943 cars in the fleet, including spares (47 cars more than the Baseline Alternative). The statistics generated from the operating plans were used to estimate annual operating and maintenance costs, with the BART O&M cost model. This model was developed by MPA with FY 2001 cost data, and recently updated for the Silicon Valley Rapid Transit Corridor.

#### ***HOV Lanes***

Most extensions or additions of HOV lanes proposed can be accommodated on existing facilities via use of existing shoulders and/or existing lanes, and do not appear to pose major impacts in implementation of these improvements.

However, the proposed new ramp structure which would carry one HOV lane parallel to West-bound I-580 from SR-24 to the Bay Bridge Toll Plaza (Section 2.1.3 of Conceptual Alternatives Report) may be very difficult to construct. Clearances and right-of-way issues need to be checked. Given the coarse level of detail for this ramp, it is suspected that the profile of the new ramp leaves very little room for clearances during construction. The ramp would require bringing the at-grade MacArthur Boulevard traffic to the same elevation as the existing I-580 and SR-24 traffic, then continuing under the new I-880 to I-80 East interchange, and over the I-80 to I-880 South and I-80 to I-580 East interchanges as well as the west-bound I-80 traffic, and finally coming back to grade over the Bay Bridge Toll Plaza. The opportunities to place both temporary supports during construction and permanent supports for the ramp are extremely limited in the I-80/I-880 interchange and the Toll Plaza areas. To minimize support impacts, the ramp will likely require

segmental construction and will likely be of structural steel to minimize formwork requirements and to minimize the weight of the structure for longer spans with minimal touchdowns. The grades required to clear interchanges and then get back down to grade may not be feasible. This ramp poses major impacts to existing buildings and businesses within the right-of-way of the north side of west-bound I-580. In particular, the new IKEA store parking facilities and the Home Depot shopping center parking facilities to the north of I-580 would be impacted. More information is required beyond the Conceptual Alternatives Report to further clarify impacts.

### ***Operational Improvements for All Corridors - Intelligent Transportation Systems (ITS)***

There are several potential Intelligent Transportation Systems (ITS) applications relevant to each of the conceptual alternatives for this project. ITS is becoming widely recognized as a cost effective solution for improving the performance and efficiency of multi-tiered transportation systems. This section considers likely ITS applications for the East-West San Francisco Bay Crossing conceptual alternatives.

The single most effective contribution ITS will make at the regional level will be the full deployment of Advanced Traveler Information System (ATIS) services. These services, whether through cell phone, kiosk, web-enabled device, or telematics (in-vehicle guidance and Mayday) will provide motorists with decision-guiding information about current transportation system performance. Providing timely traveler information will enable the public to make informed pre-trip and en-route choices regarding mode, route, and time of travel.

ITS requires a comprehensive data collection infrastructure, whether for advanced transportation management (ATMS) or for disseminating information to motorists through an ATIS. The elements of this infrastructure have historically been installed on a project-by-project basis.

### ***ITS Applications Descriptions***

The functions for each of the ITS applications are briefly defined below.

Closed-circuit television and traffic detection (e.g., inductive loops, magnetometers, microwave radar, ultrasonic, infrared, video image processing, automatic vehicle identification (AVI), and passive acoustic devices) are used to monitor real-time roadway conditions. Other sources of information include communications received from police/CHP, maintenance personnel and cellular telephone reports called in from drivers. AVI toll tags are used to deduct toll when a vehicle passes through the plaza. AVI readers may also be installed along some roadways to acquire probe vehicle data (subject to privacy protocols).

Traffic control devices such as ramp meters, lane use control signs, and signal coordination may be proactively applied to provide a better balance between freeway travel demand and capacity during congested conditions. Information may be provided to travelers through roadside traveler information devices such as

Telematics is the term used to describe data-capable wireless communications in cars. This includes auto navigation systems that provide traffic information, email, and other data useful to people on the move.

### ***ITS Application Pricing***

Because this is a planning study with a 25-year horizon, many assumptions were made in order to generically price each system for this study. We used the US DOT's ITS database to price current options. The database is available publicly on the Internet ([www.its.dot.gov](http://www.its.dot.gov)), reflects current trends and data from around the United States, and has broad acceptance among ITS practitioners.

The baseline assumption is that supporting infrastructure for each of the identified options is in place. This means, that the cost of implementation of the ITS improvement is for additional hardware and equipment, rather than for implementation and operation of an entire system developed from scratch. Most of the ITS improvements suggested have already been at least partially deployed on some or all of the Bay crossings.

## **Capital Cost Estimate Summary**

Appendix 0A presents detailed capital cost estimates for each of the alternatives and sub-options under consideration. The total project cost of Alternative 1 and each of its constituent parts is presented in Table 1.1 below.

**Table 1.1 Alternative 1 Capital Cost Summary**

<b>Item</b>	<b>Total Capital Cost</b>
4.3 Expansion of Bay Bridge Express Bus	\$67,900,000
5.0 Expansion of BART Services	\$217,100,000
7.1 ITS Improvements	\$180,000
2.1.1 Westbound Grand Avenue On-Ramp – HOV Extension	\$22,700,000
2.1.2 Westbound I-580 Left Side HOV Lane Extension	\$15,800,000
2.1.3 Westbound I-580 Right Side HOV Lane	\$74,500,000
2.1.4 Westbound I-80 HOV Improvement	\$2,900,000
2.1.6 I-80 WB Approach to Maritime/Horseshoe Off-Ramp	\$900,000
2.1.7 I-880 NB HOV Approach Extension to Market/Adeline	\$14,000,000
7.3 Expanded Bay Bridge Fastrak	\$55,000
2.1.9 HOV Improvements to First/Essex	\$22,000
2.1.10 Extension of HOV Lane on Beale/Bryant	\$537,000
2.1.11 Extension of 2 <sup>nd</sup> Street HOV Lane to King	\$23,000
2.1.12 Casual Carpool Restrictions and Formation of Loading Zones	\$18,000
2.1.13 Redesign of Sterling Street On-Ramp	\$4,800,000
2.2.2 San Mateo Bridge Fastrak Expansion	\$32,000
2.2.3 Close SR 92 HOV Gap Hesperian to I-880	\$46,100,000
4.1 SMB Expansion of Express Bus Service w/Park and Ride	\$48,300,000
2.3.3 Dumbarton Bridge Fastrak Expansion	\$37,000
2.3.4 SR 84/I-880 HOV Flyovers	\$90,500,000
4.2 Dumbarton Bridge Express Bus Expansion w/Park and Ride	\$46,100,000
<b>TOTAL ALTERNATIVE 1 CAPITAL COST</b>	<b>\$653,000,000</b>

## **Operations and Maintenance Cost Estimate Summary**

Appendix 0B presents detailed total operations and maintenance cost estimates for each of the alternatives and sub-options under consideration. The O&M cost of Alternative 1 and each of its constituent parts is presented in Table 1.2 below.

**Table 1.2 Alternative 1 Annual O&M Cost Summary**

<b>Item</b>	<b>Total Annual O&amp;M Cost</b>
4.3 Expansion of Bay Bridge Express Bus	\$30,000,000
5.0 Expansion of BART Services	\$6,600,000
7.1 ITS Improvements	\$13,000
2.1.1 Westbound Grand Avenue On-Ramp – HOV Extension	\$13,000
2.1.2 Westbound I-580 Left Side HOV Lane Extension	\$8,000
2.1.3 Westbound I-580 Right Side HOV Lane	\$21,000
2.1.4 Westbound I-80 HOV Improvement	\$4,000
2.1.6 I-80 WB Approach to Maritime/Horseshoe Off-Ramp	\$3,000
2.1.7 I-880 NB HOV Approach Extension to Market/Adeline	\$35,000
7.3 Expanded Bay Bridge Fastrak	- <sup>1</sup>
2.1.9 HOV Improvements to First/Essex	- <sup>1</sup>
2.1.10 Extension of HOV Lane on Beale/Bryant	- <sup>1</sup>
2.1.11 Extension of 2 <sup>nd</sup> Street HOV Lane to King	- <sup>1</sup>
2.1.12 Casual Carpool Restrictions and Formation of Loading Zones	- <sup>1</sup>
2.1.13 Redesign of Sterling Street On-Ramp	- <sup>1</sup>
2.2.2 San Mateo Bridge Fastrak Expansion	- <sup>1</sup>
2.2.3 Close SR 92 HOV Gap Hesperian to I-880	\$20,000
4.1 SMB Expansion of Express Bus Service w/Park and Ride	\$8,400,000
2.3.3 Dumbarton Bridge Fastrak Expansion	- <sup>1</sup>
2.3.4 SR 84/I-880 HOV Flyovers	\$17,000
4.2 Dumbarton Bridge Express Bus Expansion w/Park and Ride	\$8,900,000
<b>TOTAL ALTERNATIVE 1 ANNUAL O&amp;M COST</b>	<b>\$54,000,000</b>

<sup>1</sup> O&M Cost not calculated for improvements that only include roadway striping.

Using the annual O&M costs summarized in Table 1.2 along with anticipated farebox recovery ratios, the 20 year net O&M costs for alternative 1 were calculated. These costs are summarized in Table 1.3.

**Table 1.3 Alternative 1 Net O&M Cost Summary (Millions)**

<b>Improvement</b>	<b>Annual Operating Cost</b>	<b>Farebox Recovery Ratio</b>	<b>Net Annual Operating Cost</b>	<b>20-year Net Operating Cost</b>
HOV Improvements	0.2	n/a	0.2	4.0
Express Bus	\$47.2	50%	\$23.6	\$471.1
BART	\$6.6	58%	\$2.8	\$56.2
<b>TOTAL ALT 1</b>	<b>\$54.0</b>	-	<b>\$26.6</b>	<b>\$531.3</b>

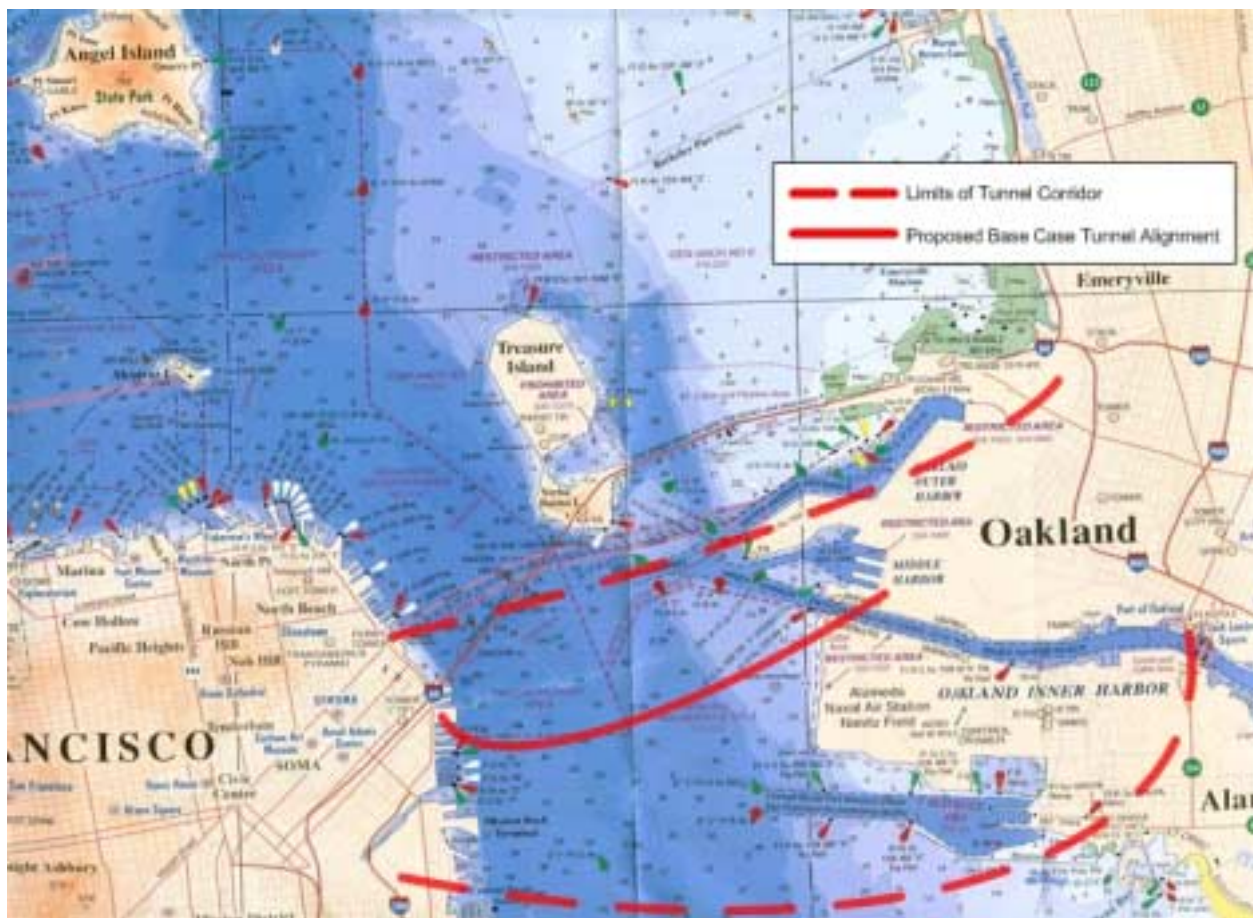
### ***ALTERNATIVE 2: RAIL / BART IMPROVEMENTS IN THE BAY BRIDGE CORRIDOR***

Crossing alternatives were considered for a BART type Rapid Transit System, Conventional Rail and High Speed Rail systems.

#### **General Considerations**

Corridor alignment selection was a function of the landside connection and the bay crossing conditions. The following summarizes the rationale behind selecting the base case alignment.

A bored tunnel will require adequate cover in order to prevent surface disturbance as well as counteract the effects of buoyancy. Alignments that avoid the deep (120 ft. below MLL) shipping channels are favored because they allow for relatively shallow approaches and reasonable approach grades. South of Latitude 37° 47' 30" the Bay depth along the shipping channel varies between 75 feet below MLL to 60 feet below MLL.



**Figure 2.1: Band of Potential Tunnel Alignments for BART & RAIL**

Another factor in locating the tunnel is the site geology. The conceptual alignment considered previous studies (Ref. #2 & #3) that have identified and defined much of the Bay Mud and Bedrock profiles under SF Bay. Alignments that resulted in relatively uniform tunneling conditions (consistent soil strata), and minimized modifications (a.k.a. “dressing”) to the cutting face of the Tunnel Boring Machine (TBM) were favored over those alignments that crossed through extreme variations in soil conditions. Uniform soil conditions also help minimize hard points in the soil-tunnel system thereby improving seismic performance of the system.

## **BART Corridor**

### ***Corridor Improvements***

Appendix 2A contains an ancillary study commissioned to identify BART Bay Bridge Corridor improvements on the Market Street Line and the Trans Bay Tube west of Yerba Buena Island, which did not involve a new bay crossing. This is referred to as the “Break-Out” Alternative. The conclusion of this effort was that while not impossible, branching out of the current BART alignment carried significant cost risk due to the fact that the improvements would cause very serious temporary and permanent surface impacts to Market Street, The Embarcadero, the Ferry Building and several high-rise properties along the Market Street Corridor.

### *Bay Crossing*

A sub-aqueous trans-bay crossing was envisioned to be the most likely alternative to carry BART. Initially a parallel Immersed Tube Tunnel (ITT) was considered. The construction technology would be very similar to that employed for the original Trans Bay Tube construction (bid in 1965). An ITT requires that a trench be excavated and made ready to receive a prefabricated tunnel segment that is sunken into its final position. These segments are then joined together to form a continuous guide-way and then backfilled with engineered soil.

A primary goal for BART in creating another Bay crossing is to create redundancy for the BART system. However, a parallel structure to the existing Tube carries the same seismic risk and hazard as it travels through the same soil strata. To reduce the seismic hazard, it is important for the new crossing to have a different alignment than the existing. Further, although straightforward and “done before”, an ITT carries inherent environmental impacts to the Bay and vessel traffic to and from the Port of Oakland and points south. Bay impacts that were acceptable in 1965 are now seen in a different light, so other non-intrusive technologies were explored. As a result, the ITT option was screened out mainly due to seismic safety and environmental issues.

The least intrusive way to construct a tunnel is to bore it. The original studies for the BART Trans Bay Tube considered bored tunnels by means of a tunneling shield. This method was screened out at the time due to concerns about working conditions in a compressed air environment. The last ten years have seen major advancements and rapid maturation of Tunnel Boring Machine (TBM) technologies for large diameter bores.

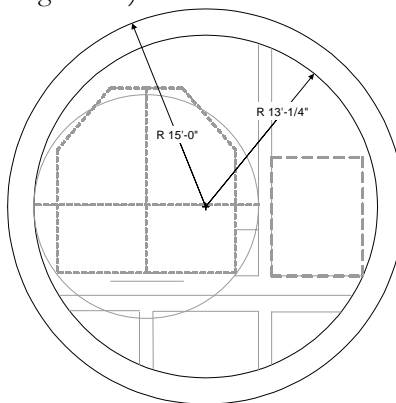
The technology limits workmen’s exposure to compressed air conditions which also reduces problems with soil settlement, disposal of soils and keeping the tunnel aligned. As a result, tunnel boring by TBM has become a competitive alternative to ITT in areas with soft soils.

### *Type*

Twin bored tunnels, with bores created by a Tunnel Boring Machine (TBM) with positive face control. Liner is assumed to be installed in a single pass and to be made of tapered pre-cast reinforced concrete segments.

### *Size*

It was assumed that each bore would accommodate one track and third rail as well as gallery, exhaust and drainage space that is commensurate with the existing Trans Bay Tube. The resulting conceptual tunnel bore diameter was assumed to be 30-ft. (See Figure 2.2).



**Figure 2.2: Conceptual Cross-Section – 2nd BART Trans Bay Tube**

**Location:**

Figure 2.1 shows the limits of the band of potential tunnel alignments and the approximate location of the base-case alignment selected for this study. The base-case alignment is also highlighted in Figure 2.3.



**Figure 2.3: Location of 2<sup>nd</sup> BART Trans Bay Tube**

The following alternative East Bay connections to BART were considered:

- A branch from MacArthur that would continue under Broadway filling in the so called “4<sup>th</sup> Bore”
- A branch from MacArthur that would be routed under Franklin Street
- A branch between West Oakland Station and the Trans Bay Tube
- A branch from the West Portal of the Oakland Wye

The final alternative was determined to be feasible, constructible and fulfill the functional requirement of providing redundancy to the BART system while mitigating seismic hazard.

**Oakland Approach**

This discussion is limited to the chosen branch line origin, the Portal of the Oakland Wye.

Components of the Oakland Approach:

- Breakout of Approach to Portal of the Oakland Wye
- New Line from Wye Approach that dives underground
- Rerouting, to the south, of existing line between West Oakland Station and the Wye
- Creation of a Bi-level Jack London Square BART Station (Existing BART on Top/ New BART lines Below)
- Demolition of the bypassed existing line between West Oakland and the Wye
- Cut and Cover Tunnel to 3<sup>rd</sup> Street and I-880
- Bored Tunnel under I-880/ Rail Yards and Port of Oakland
- Ventilation Shaft

### ***San Francisco Approach***

Components of the San Francisco Approach:

- Ventilation shaft
- Bored tunnels down Main Street
- New Station with ability to connect to proposed Trans Bay Terminal (Bus & HSR)
- Bored tunnel crossing Market and Montgomery via Second Street
- Transfer Station at Post Street near Market and Montgomery
- Bored tunnel down Post Street
- Terminal station at Union Square with transfer to proposed underground MUNI line

### **RAIL/ High Speed Rail Corridors**

#### ***Bay Crossing***

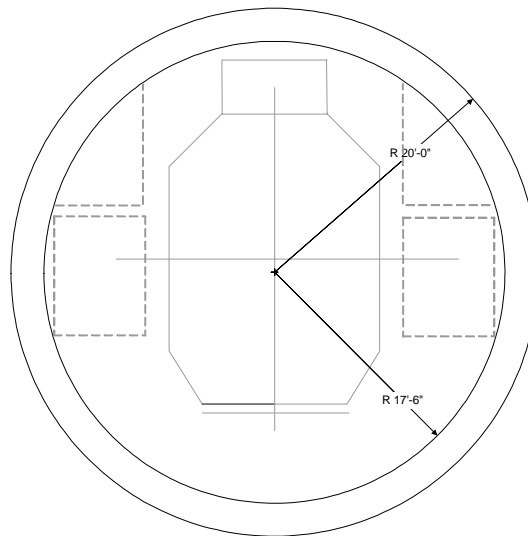
Current Trans Bay Terminal (TBT) studies show two potential entry points into the TBT in San Francisco. This study initially considered ITT technology for this corridor, however as with the BART alternative, tunneling using Tunnel Boring Machines is considered more likely. As a result, the most likely sub-aqueous crossing will be a pair of bored tunnels each carrying one track.

#### ***Type:***

Twin bored tunnels, with bores created by a Tunnel Boring Machine (TBM) with positive face control. Liner is assumed to be installed in a single pass and to be made of tapered pre-cast reinforced concrete segments.

#### ***Size:***

It was assumed that each bore would accommodate one track and overhead electrification as well as space for a pantograph and a gallery, exhaust and drainage space that is commensurate with the existing Trans Bay Tube. As a result, the conceptual section in Figure 2.4 is considered representative. Optimal proportioning will consider detailed maintenance and safety requirements and is expected to result in a cross section no greater in size than the conceptual cross section-section.



**Figure 2.4: Conceptual Cross-Section – RAIL & HSR**

**Location:**

Referring to Figures 2.5 and 2.6, we note that the bulk of the observations for the BART corridor apply to the rail corridor as well, due to the fact that the both lines are assumed to connect to, (as in the case of conventional rail), or be in the vicinity of, (as in the case of BART), to the proposed new Trans Bay Terminal.



**Figure 2.5: Rail Improvements in the Bay Bridge Corridor – SF to Oakland/Emeryville**

The exception is the connection to existing lines on the Oakland side. For the conventional rail alternative the connection alternatives are:

- Connection to both Oakland and Emeryville (See Figure 2.5)
- Connection only to line from Emeryville (See Figure 2.6)



**Figure 2.6: Rail Improvement in the Bay Bridge Corridor – SF to Emeryville only**

For the Oakland connection, the following parameters were used to narrow down its location:

- Connection that allowed for relatively shallow crossings under BART trans bay line
- Connection points that allowed for tunnel boring under the Port of Oakland and I-880

### ***Oakland Approach***

Two options were explored that represent the lower and upper cost for this alternative.

- Option-1: Connect only to Line from Emeryville
- Option-2: Connect to both the Emeryville and Oakland Lines

As with the BART approaches, each option carries a higher contingency than the bay crossing itself due to the lack of definition of approach line work. The limits of the Oakland Line for Option-2 were defined to be compatible with the limits of work assumed for the BART improvements. For this study the project limits were assumed to begin:

- At West Grand for the existing rail line from Emeryville
- At Clay Street for the existing Oakland rail line adjacent to Embarcadero West

The following was assumed for Option 1:

- Trains from Emeryville are able to cross the Bay. Double track approaches would connect the approach line to the bay crossing at the vent shaft.
- At the proposed location of the vent shaft it was assumed that the shaft would accommodate a future switch and space for a future breakout that would enable trains to head to either Emeryville or to the Oakland line along the Embarcadero.

The following was assumed for Option 2:

- Trains from Emeryville are able to cross the Bay or head to Embarcadero West. Trains from the South Bay have the option of crossing the Bay or heading to Emeryville. Double track approaches would connect the approach line to the bay crossing at the vent shaft
- It is assumed that the line along the Embarcadero is below grade. It is assumed that the approach branching from the Emeryville line will dive below grade to the same elevation as the approach from the line along the Embarcadero.
- At the proposed location of the vent shaft, it was assumed its size would accommodate a switch to enable trains to head to either Emeryville or to the line along the Embarcadero.
- One station was assumed, known as the Jack London Multi Modal Station (JLS), which would enable transfer from regional Commuter Rail or High-Speed Rail to BART.

### ***San Francisco Approach***

The limits of the approach were assumed to begin at the San Francisco vent shaft and terminate at the currently proposed Trans Bay Terminal (TBT). The TBT currently under study allows for two potential bay crossing connections, one originating at Mission Street the other originating at Main Street.

The latter was chosen as the base assumption for this study as it is more compatible with the assumption that the bay crossing is more likely to be a bored tunnel than an immersed tube tunnel. As a result, the approach path from the SF vent runs down the center of Main Street.

### **Cost Estimate Element**

This planning level estimate includes:

- Labor Costs
- Fixed Costs (site setup, plant, materials, etc.)
- Variable Costs (time related such as TBM progress, logistics, learning curve)

- Overheads and Profit
- Rail Systems in the Tunnel

Project costs are subject to the following risks, which the contingencies at this stage serve to capture:

- Design risks
- TBM manufacturing delays
- Delays in site setup (TBM preparations, liner Segment fabrication & delivery)
- TBM operating problems
- TBM utilizations and logistical problems
- Scope of Owner's safety protocols
- Adverse ground conditions
- Strikes
- System start-up

As a point of reference, the original construction cost of the existing Trans Bay Tube was \$102 Million (Bid Year 1965) for 3.7-miles of Immersed Tube Tunnel (Ref. 1). Table 2.1 summarizes projects of similar scope in order to put the proposed bay crossing into perspective.

**TABLE-2.1: Comparable Recent Tunnels and Subaqueous Tunnel Crossings**

<i>Tunnel</i>	<i>Year Open</i>	<i>Length</i>	<i>Bore Diam.</i>	<i>Type</i>	<i># of Bores</i>	<i>Total Cost (Approx.)</i>	<i>Cost/Rte Mile (Approx.)</i>	<i>Cost per Tunnel/ Foot (Approx.)</i>
St. Clair USA –Canada	1994	1.8 km (1.1 mi)	9.5m (31-ft)	Rail	1	\$270 Mn	\$245 Mn	\$46,500 <sup>2,3</sup>
Mercer Street Seattle-USA	2000	1.8 km (1.1 mi)	5.1m (17-ft)	Sewage	1	\$29.5 Mn	\$25 Mn	\$4,735 <sup>1</sup>
Channel Tunnel UK-France	1994	50 km (31mi)	8.8m (29-ft)	Rail/HSR	2 (+ svc)	\$14 Bn	\$448 Mn	\$ 40,000 <sup>2</sup>
Trans Tokyo Bay Hwy	1998	10 km (6.2 mi)	14.2m (46-ft )	Hwy	2	\$15 Bn	\$2.42 Bn	\$229,000 <sup>2</sup>
Madrid Metro Spain	1999	37.5 km (23.3 mi)	9.33m (31-ft)	Rail	2	\$1.7 Bn	\$56 Mn	\$5,300 <sup>2</sup>
Westerschelde Netherlands	2002	2.1km (1.3 mi)	11.33m (37-ft)	Hwy	2	\$682 Mn	\$523 Mn	\$49, 510 <sup>2</sup>
Groene Hart Netherlands	2004 Finish	7 km (4.3 mi)	14.87m (48-ft)	Rail/HSR	1	\$349 Mn	\$81 Mn	\$15, 370 <sup>1</sup>
Groene Hart Netherlands	Proposed <sup>4</sup>	7 km (4.3 mi)	9.3 (31-ft)	Rail/HSR	2	\$419 Mn	\$96 Mn	\$18,180 <sup>1</sup>
North –South Contract 4 Netherlands	2008 Finish	3.8 (2.4mi)	7m (23-ft)	Rail	2	\$960 Mn	\$386 Mn	\$36,590 <sup>1</sup>
Freight Tunnel NYC	Proposed 2002	Approx. 6-mi	-	Heavy Rail	1	\$1.5 Bn <sup>6</sup>	-	-
Freight Tunnel NYC	Proposed 2002	Approx 6-mi	-	Heavy Rail	2	\$2.5 Bn <sup>6</sup>	-	-
New Jersey Transit Corridor NJ/NYC	Proposed 2002	Approx 7-mi	-	Rail	2	\$4 to 5Bn <sup>7</sup>	-	-
Sound Transit Seattle- USA	Proposed	4-mi	2--ft	Light Rail	2	\$800 Mn	\$200 Mn <sup>1</sup>	19,000 <sup>1</sup>
Back Channel Long Beach	Proposed 2001	1.2 km (0.75 mi)	14.2m (46-ft)	Hwy	2	\$728 Mn	\$960 Mn	\$91,000 <sup>2</sup>
Back Channel Long Beach	Proposed 2001	1.2 km (0.75 mi)	12.2m (40-ft)	Hwy	2	\$485 Mn	\$650 Mn	\$62,000 <sup>2</sup>
New BART San Francisco	Proposed 2002	4.2 mi	30-ft	Rail	2	\$1.5 Bn	\$350 Mn	\$22,000 to \$33,000 <sup>2,5</sup>
New Rail San Francisco	Proposed 2002	4.2 mi	40-ft	Rail/HSR	2	\$2.0 Bn	\$480 Mn	\$32,000 to \$45,000 <sup>2,5</sup>

Notes: Costs were obtained from various publishes sources and have not been corrected to a common reference year.

1. Guide-way Cost
2. Guide-way plus Systems/Facilities
3. TBM & Liner purchased by Owner
4. Original alternative w/ cross passages at 1200-ft
5. Planning Level Engineers Estimate = Unit Cost (w/o 35 % contingency & project implementation cost)
6. Estimate Equivalent to Planning Level Engineer's Estimate that includes improvements to existing rail infrastructure on both sides of harbor – Project Study is Ongoing
7. Conceptual Cost Estimate – Project Study Is Ongoing

### ***Promising World Trends***

The cost trend for tunnels is downward as evidenced by following summary of the cost per route mile of recently constructed underground Metro extensions (REF # Madrid Metro Web Site):

- London – 1991 to 1999 at cost of \$375 Million/km (\$600 Million/mile)
- Athens – 1987 to 1999 at cost of \$156 Million/km (\$250 Million/mile)
- Paris - 8 year construction at a cost of \$155 Million/km (\$250 Million/mile)
- Lisbon - 8 year construction at a cost of \$118 Million/km (\$189 Million/mile)
- Madrid – 1995 to 1999 at cost of \$30.3 Million/km (\$49 Million/mile)

### **Operations Summary**

#### ***BART***

This alternative assumes a second Transbay Tube with service to Union Square. This alternative was modeled with 60 trains/hour crossing through both tubes (30 trains per hour through each). However, the line loads obtained indicate that this level of service is not warranted. Therefore, we revised the operating plan for this alternative with 45 trains/hour through both tubes. This plan assumes 12-minute service for each of the five routes through the existing tube, resulting in 25 trains/hour (10 trains/hour from Pittsburgh, 5 trains/hour from Richmond, 5 trains/hour from San Jose and 5 trains/hour from East Dublin). Another twenty (20) trains per hour would cross through the proposed new tube (5 trains/hour from Richmond, 5 trains/hour from Pittsburgh, 5 trains/hour from East Dublin and 5 trains/hour from Fremont). Ten-car trains are required for routes through the existing tube. Eight-car trains (average) are required for routes through the new tube. Alternative 2 requires 1,213 cars in the fleet, including spares (317 cars more than the Baseline Alternative).

#### ***Conventional Rail***

The conventional rail operating plan for the Bay Bridge corridor includes six trains per hour during the peak commute hour. A total of 18 commuter rail trains, including spares, would need to be purchased to implement the proposed service plan, which would serve the forecast demand.

### **Capital Cost Estimate Summary**

Appendix 0A presents detailed capital cost estimates for each of the alternatives and sub-options under consideration. The total project cost of BART in Alternative 2 and each of its constituent parts is presented in Table 2.2a below. The total project cost of Conventional Rail in Alternative 2 and each of its constituent parts is presented in Table 2.2b. As previously discussed, high end and low end capital cost estimates have been prepared. Tables 2.2a and 2.2b summarize this cost range.

**Table 2.2a Alternative 2 Capital Cost Summary - BART**

Item	Total Capital Cost
<b>High-Range Estimate</b>	
Crossing	\$2,980,000,000
Approach	\$5,780,000,000
ROW	\$53,000,000
Rolling Stock	\$1,460,000,000
<b>SUBTOTAL</b>	<b>\$10,270,000,000</b>

<b>Low-Range Estimate</b>	
Crossing	\$2,070,000,000
Approach	\$3,520,000,000
ROW	\$53,000,000
Rolling Stock	\$1,460,000,000
<b>SUBTOTAL</b>	<b>\$7,100,000,000</b>

**Table 2.2b Alternative 2 Capital Cost Summary – Conventional Rail**

Item	Total Capital Cost
<b>High-Range Estimate</b>	
Crossing	\$4,080,000,000
Approach	\$7,440,000,000
ROW	\$25,000,000
Rolling Stock	\$223,000,000
<b>SUBTOTAL</b>	<b>\$11,770,000,000</b>

<b>Low-Range Estimate</b>	
Crossing	\$2,880,000,000
Approach	\$4,360,000,000
ROW	\$25,000,000
Rolling Stock	\$223,000,000
<b>SUBTOTAL</b>	<b>\$7,490,000,000</b>

## **Operations and Maintenance Cost Estimate Summary**

Appendix 0B presents detailed operations and maintenance cost estimates for each of the alternatives and sub-options under consideration. BART operating statistics were estimated with a model developed by Manuel Padron & Associates and calibrated to actual FY 2001 BART statistics. A memorandum describing this analysis is attached in Appendix 1B. The O&M cost of Alternative 2 and each of its constituent parts is presented in Table 2.3 below.

**Table 2.3 Alternative 2 Annual O&M Cost Summary**

<b>Item</b>	<b>Total Annual O&amp;M Cost</b>
3.4 San Francisco – Oakland BART	\$133,640,000
3.7 San Francisco – Oakland Conventional Rail	\$18,100,000
<b>TOTAL ALTERNATIVE 2 ANNUAL O&amp;M COST</b>	<b>\$151,700,000</b>

Using the annual O&M costs summarized in Table 2.3 along with anticipated farebox recovery ratios, the 20 year net O&M costs for alternative 2 were calculated. These costs are summarized in Table 2.4.

**Table 2.4 Alternative 2 Net O&M Cost Summary (Millions)**

<b>Improvement</b>	<b>Annual Operating Cost</b>	<b>Farebox Recovery Ratio</b>	<b>Net Annual Operating Cost</b>	<b>20-year Net Operating Cost</b>
BART	\$133.6	58%	\$56.6	\$1,132.7
Conventional Rail	\$18.1	38%	\$11.1	\$222.6
<b>TOTAL ALT 2</b>	<b>\$151.7</b>	<b>-</b>	<b>\$67.7</b>	<b>\$1,355.3</b>

## **Conventional Rail – East Bay South Leg**

Through the course of the study and public outreach activities a number of questions were raised relative to the need for the southern leg of the conventional rail improvement's East Bay leg. In response to those concerns, the capital and operational costs of this leg have been isolated. They are as follows:

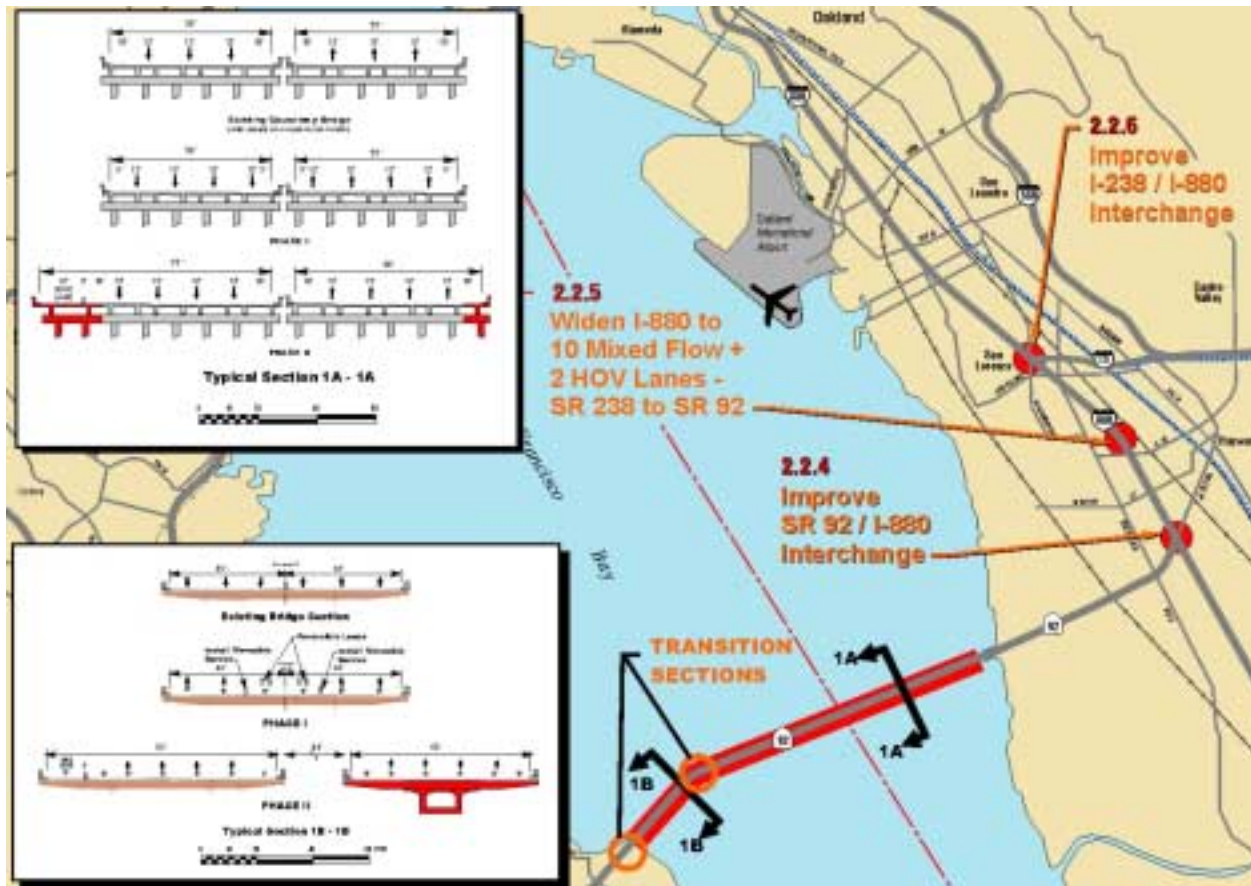
- East Bay southern leg capital cost - \$3.8 Billion (high end) to \$3.1 Billion (low end);
- Annual Operations Cost - \$8.5 Million; and
- 20 Year Net Total Operating Cost - \$104.8 Million.

**References:**

1. Subway Construction Costs, SFBA RTD (BART), compiled by T.R. Kuesel April 1971
2. Engineering Geology of San Francisco Bay, California by P.D Trask & J. W. Rolston, Bulletin of the Geological Society of America, September 1951
3. Geologic and Engineering Aspects of San Francisco Bay Fill, Special Report 97, California Division of Mines and Geology, 1969
4. Chart Map & Guide – San Francisco Bay Golden Gate Channel Crossing Press, 1998

**ALTERNATIVE 3: HAYWARD – SAN MATEO BRIDGE CORRIDOR IMPROVEMENTS**

This alternative proposes to implement two separate phases of improvements: Phase I – Install reversible lanes on High Bridge with a re-striping of the Causeway sections; and Phase II – Widening of the San Mateo Bridge.



**Figure 3.1. Overview of San Mateo Bridge Corridor Improvements**

Though proposed as a “widening” of the San Mateo Bridge, the widening structure will be a major bridge in and of itself. The existing 7-mile San Mateo-Hayward Bridge, when considered from shore to shore, is the 10th longest bridge structure in the world. Furthermore, the 750 foot main span over the shipping canal at 750 feet long currently ranks as the 17<sup>th</sup> longest orthotropic steel double box girder bridge span in the world. When these factors are taken into consideration, the “widening” structure will, in fact, be an important and significant infrastructure undertaking.

### **Structural Design Issues**

Phase I - No significant engineering issues are associated with the use of the moveable barrier system as it has been used on bridges with similar bridge deck types.

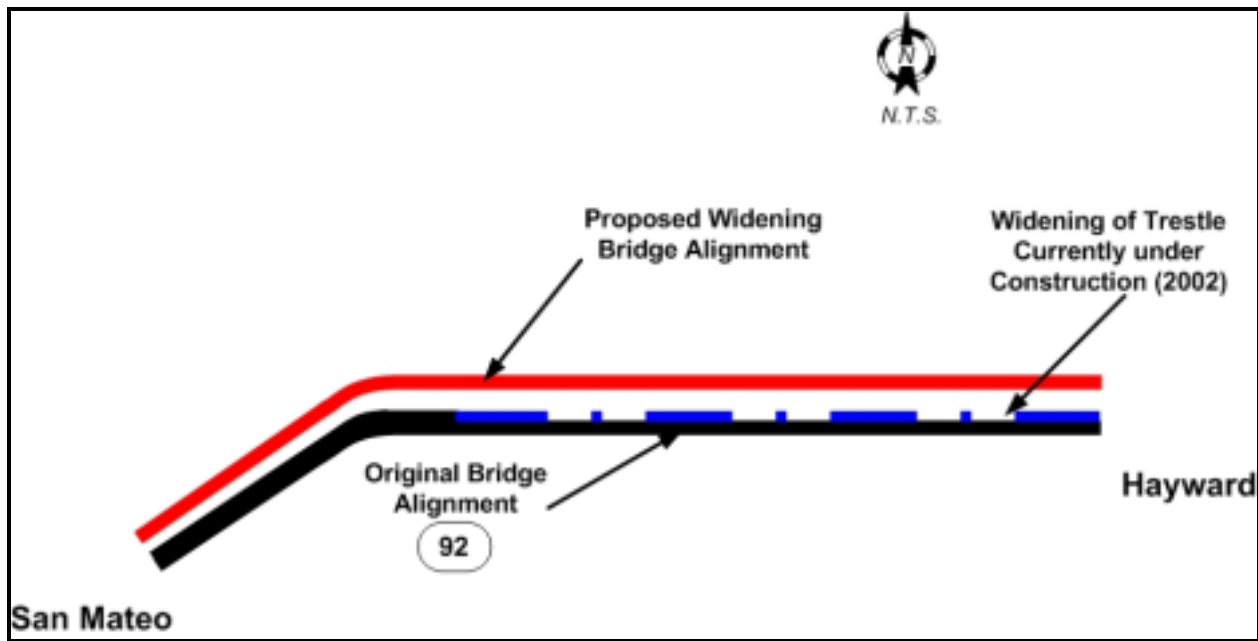
Phase II – Several preliminary options for widening the existing San Mateo Bridge were explored. Initially, the goal for the widening was to try to create a widening in which the new lanes are continuous with the existing, and a continuous driving surface is maintained. As mentioned in the Draft Screening Report (Nov. 2001), cantilever sections cannot be added to the existing high bridge to provide a continuous, widened roadway surface due to structural constraints. The proposed solution calls for new bridge facilities to be placed immediately adjacent to the existing bridge, matching the existing grade lines to facilitate additional lanes for the high rise section of the bridge.

The existing bridge deck of the high rise section is typically 85'-2" wide. The widening proposes to add one lane in each direction, or approximately 24' total of new roadway surface. The feasibility of such widening is limited by several practical considerations, including the size of foundation required for a new bridge, the geometric constraints of the existing bridge imposed on the new widening alignment, and the seismic performance and design of the new system.



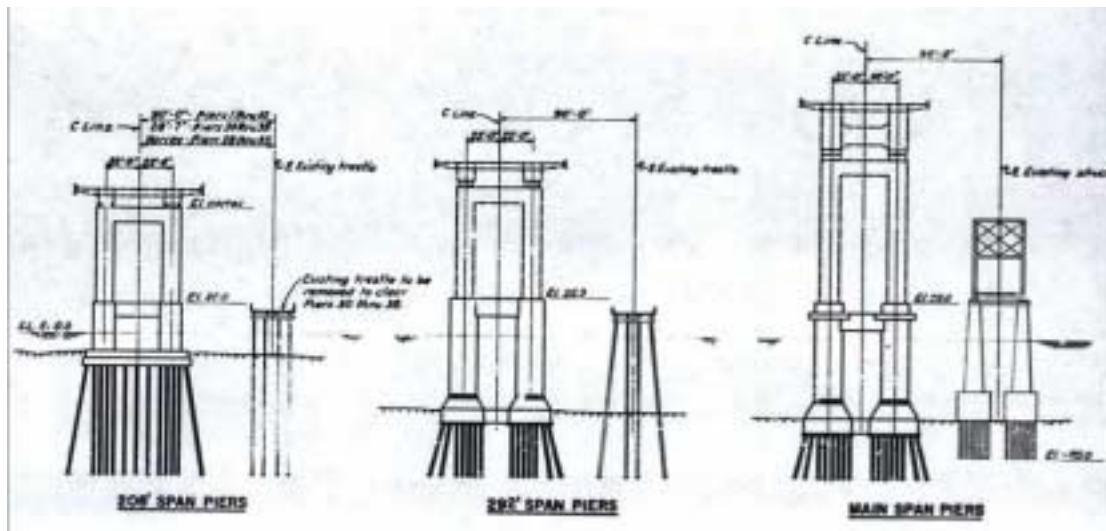
**Figure 3.2. View of Existing San Mateo Bridge** (Photo Courtesy of Ref. 3.1)

The originally proposed alignment and cross sections for the widening shown in Figure 3.1 must be modified slightly such that all widening occurs along the northern side of the existing bridge. Review of the current structure shows that power lines and transmission towers run on the south side of the bridge, parallel to the structure (Figure 3.2). The proximity of power lines constrains construction and structural clearances on the south side of the bridge making this a less favorable configuration for widening. Therefore, for the purposes of this study, all cost estimates were based on the assumption that widening on all structure types would occur on the north side of the existing alignment. The modified alignment and location of new widening structures are shown in Figure 3.3.



**Figure 3.3. Schematic Plan View of Alignment for San Mateo Bridge Widening**

Preliminary review of existing plans shows that many of the existing high-rise pier foundations utilize battered piles along the exterior of the bell foundations. (See Figure 3.4.) Further review of the most recent seismic retrofit of the foundations for the San Mateo Bridge shows that many of the piers with rectangular footings required a 3-ft. reinforced concrete overlay of the pile cap to provide added strength and ductility. For Piers 2-5 and Piers 34-37 of the high-rise bridge, the foundations were retrofitted well outside the footprint of the existing bridge foundation to include corner 8 to 12 ft. diameter CISS or CIDH piles and a new precast frame to connect the new corner piles to the existing foundation.



**Figure 3.4. Elevation of Existing Piers on High Bridge and Main Span**

The centerlines of these retrofit large diameter CISS and CIDH piles are typically 48 to 49 ft. from the centerline of the existing bridge. (See Figure 3.5.)

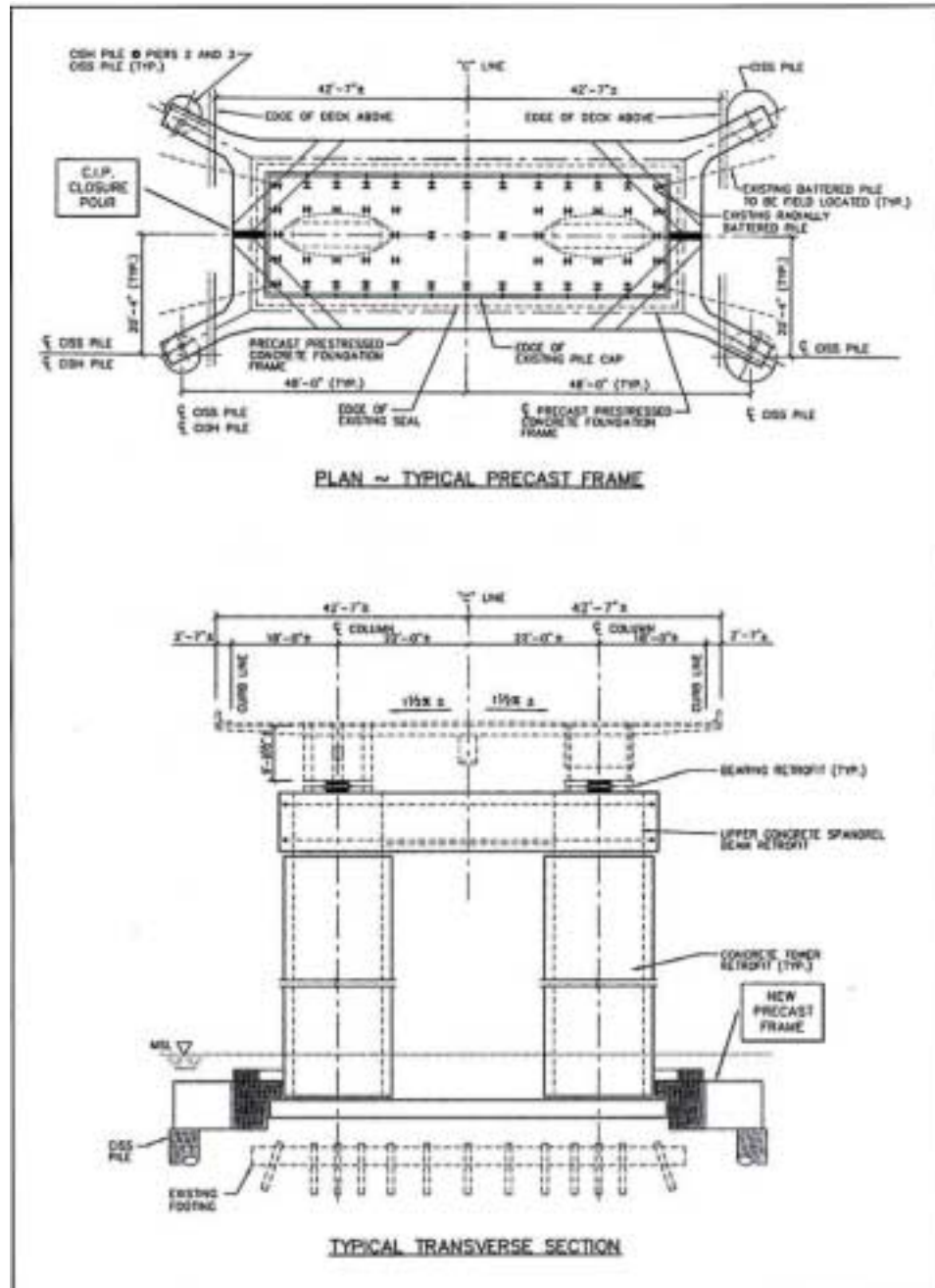
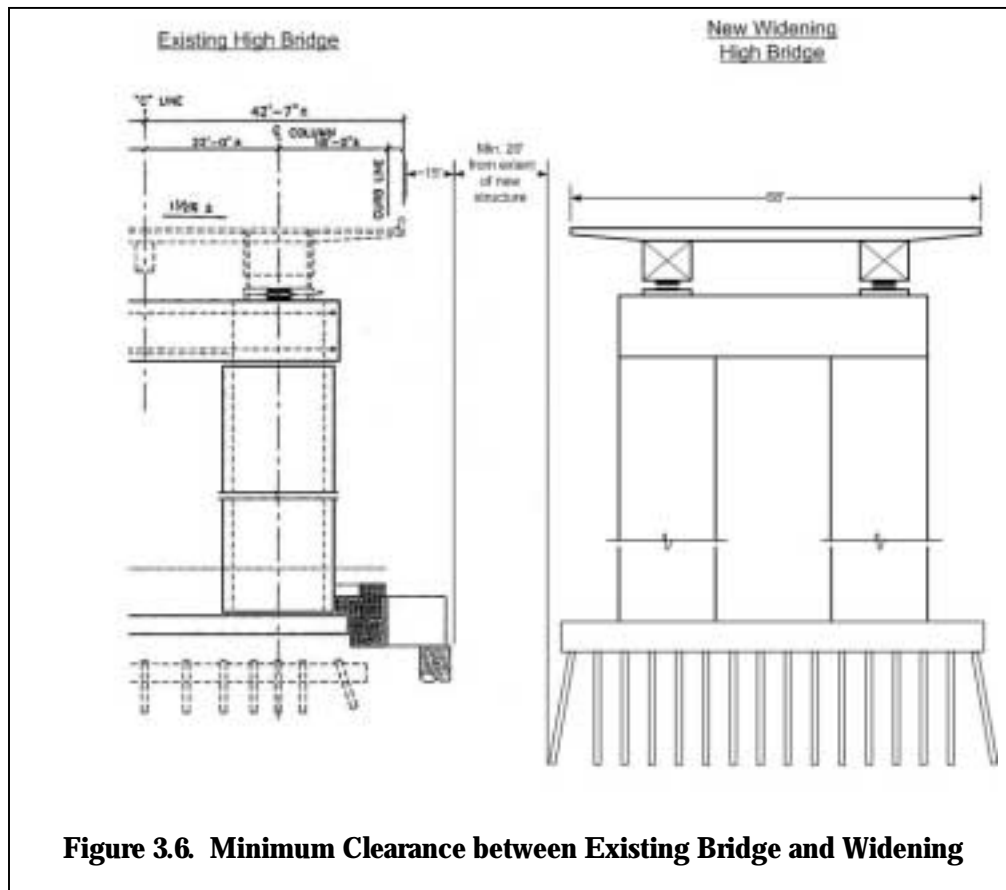


Figure 3.5. Retrofit of Existing Bridge Foundation

Considering these geometric constraints, the exterior edge of foundations to support the widening lanes would be at a minimum of 78 feet from the existing centerline of the bridge (see Figure 3.6). Assuming the widening bridge structure is as wide as its new foundation, the edges of the bridge deck widening and the existing bridge would be separated by approximately 25 feet or more. This is a relatively large distance to span between the two structures and create a continuous riding surface. The width of the widening, including a “closure structure” between the two bridge decks, would have to be at least 70 to 80 feet in order to create a continuous riding surface with the existing roadway. This width of roadway would be commensurate to an entirely new parallel San Mateo Bridge structure, rather than a small 24 ft. widening. Hence, the proposed widening is likely to be a parallel, but independent bridge, particularly for the high bridge structure.



Using separate structures for widening creates an opportunity to decrease the seismic hazard and increase the overall performance of the bridge system. The new widened structure would have separate foundations and may therefore respond very differently from the existing structure during a large seismic event.

The idea for using an independent parallel structure is supported by the widening for the existing low viaduct portion of the San Mateo Bridge currently under construction. The new trestle structure is immediately adjacent to the existing trestle, but will still maintain a 4-ft separation, and have its own foundation from the existing bridge trestle.

### *Bay Crossing*

The crossing itself is limited to widening the causeway (trestle) by 68 ft. and creating a new high bridge also 68 ft wide. The crossing spans between the East toll plaza and the viaduct approaches to SR-92 on the West side. Further, reversible lanes on the new high bridge with a movable barrier will be incorporated to help handle peak traffic flows during commute hours.

Option 1 for the San Mateo Bridge widening is an added bike lane (additional 12 feet in width). The 12 feet is considered as an optional cost on the trestle as well as the high bridge and main span portions of the structure.

### *Type:*

The causeway was assumed to be a trestle structure similar to the current widening under construction, employing precast girders and driven pile supports.

The structure type, particularly on the high bridge, is driven by the length of the main span required over the navigation channel (approximately 750-850 ft) as well as the height limitations for supports imposed by glide paths for nearby San Francisco Airport air traffic. The glide path requirements restrict the use of cable-supported spans, such as cable stay or suspension bridge types. Most of the high bridge can be comprised of precast concrete segmental box girders, however, there are very limited girder type bridges which can span a navigation channel of this length with the required clearances and resist large seismic induced loads. It is proposed that a steel box with orthotropic deck, as is currently used on the existing bridge structure, also be implemented for the main spans of the widening.

### *Size:*

The trestle structure is approximately 5 miles long. The new high bridge is approximately 2 miles long. The high bridge will incorporate a main span similar to the existing bridge, 850 ft. long. For purposes of this study, the width of the widening (trestle and high bridge) is assumed 68 ft.

The bike lane adds 12 ft of width to the trestle and high bridge. The bike lane would be designed to carry emergency vehicle traffic, and therefore is estimated similarly to the vehicular bridge itself. The cost for the bike lane may decrease if load ratings are decreased resulting in a lighter structure, but only if alternate emergency access plans are also in place.

### *Location:*

The alignment of the widening for both the trestle and the high bridge will be to the north of the existing structure. The southern alignment is constrained by existing powerlines and towers. The high bridge main span must clear the navigation channel by 135 ft above MSL. The SF Airport glide path restricts any obstruction over 200 ft. above MSL.

### *East Bay Approach*

East Bay Approach improvements include two major regions of impact:

- Region 1: Improvements to I-880/SR-92 Interchange;
- Region 2: Widening of I-880 between SR-238 and SR-92.

Major items for Region 1 include:

- New aerial ramp (24' wide/1 lane)
- New at-grade lane
- Reconstruction of Calaroga Ave. Bridge
- New aerial ramp (50' wide/2 lanes)
- ROW Acquisition (including acquisition of single family homes along route)

Major Items for Region 2 include:

- New at-grade lane
- Bridge widening
- Relocation of soundwalls
- Reconstruction of overpass (12' wide)
- Reconstruction of the Winton Ave. Interchange
- ROW acquisition (including acquisition of single family homes along route)

### **San Mateo Bridge Widening and East Bay Approach Improvement Cost Elements**

Costs for constructing the new trestle were based on current Bay Area trestle contracts under construction. Bid documents were reviewed for the Richmond San Rafael trestle replacement project and the current San Mateo Bridge trestle widening. These projects were considered to be very good indicators for costs given the proximity of the locations of each project relative to this alternative as well as the type and scope of construction undertaken.

Costs for estimating the high bridge carry slightly more risk than the trestle portion of the structure. This is caused by several factors. The high bridge, while predominantly precast segmental concrete, includes a portion of steel on the main spans. Steel bridge structures have not been constructed in the Bay Area since the existing San Mateo Bridge was built in the 1960's. The main spans of the new Bay Bridge East Span have been designed using steel; however bids for construction have not yet been tendered. The outcome of this project may greatly influence the price for steel structures on this widening alternative. Another challenge for this project is the complex issue of schedule and fabrication of large steel structures in the US. Procurement from other countries such as China and Japan is complicated by current market trends.

The East Bay approach improvements carry higher project contingencies than the crossing itself due to larger impacts to traffic and landside disruption. Unlike the crossing itself, the associated unknowns with construction, environmental remediation, and traffic re-routing during construction are greater and therefore carry a much higher risk for the project as a whole. These risks and the contingencies associated with them typically tend to decrease as the scope of the project is better defined and impacts are more accurately established and weighted. As the goal of the project was to capture the order of magnitude costs of improvements, Caltrans cost data was used to quickly estimate the approach improvement items.

To add perspective to the current cost estimates, the cost to build the original San Mateo Bridge in 1967 was \$70 million dollars (in Year 1967 dollars). Retrofit costs of the existing San Mateo Bridge were on the order of \$190 million dollars (in Year 1996 dollars). A significant portion of the retrofit cost was to improve

foundation strength and ductility of the high rise portion of the structure. The widening of the trestle structure currently under construction costs \$112.9 million dollars (in Year 1999 dollars), including toll plaza improvement costs.

### **Capital Cost Estimate Summary**

Appendix 0A presents detailed capital cost estimates for each of the alternatives and sub-options under consideration. The total project cost Alternative 3 and each of its constituent parts is presented in Table 3.1 below. As previously discussed, high end and low end capital cost estimates have been prepared. Table 3.1 summarizes this cost range.

**Table 3.1 Alternative 3 Capital Cost Summary**

<b>Item</b>	<b>Total Capital Cost</b>
<b>High-Range Estimate</b>	
Phase I – Reversible Lanes on High Bridge	\$40,100,000
Phase II – Widen Causeway and High Bridge	\$1,883,000,000
Improve I-880/SR 92 Interchange	\$228,000,000
Widen I-880 between SR 238 and SR 92	\$192,000,000
Improve I-880/I-238 Interchange	\$12,800,000
<b>SUBTOTAL</b>	<b>\$2,356,000,000</b>
<b>Low-Range Estimate</b>	
Phase I – Reversible Lanes on High Bridge	\$40,100,000
Phase II – Widen Causeway and High Bridge	\$1,579,000,000
Improve I-880/SR 92 Interchange	\$228,000,000
Widen I-880 between SR 238 and SR 92	\$192,000,000
Improve I-880/I-238 Interchange	\$12,800,000
<b>SUBTOTAL</b>	<b>\$2,052,000,000</b>

## **Operations and Maintenance Cost Estimate Summary**

Appendix 0B presents detailed operations and maintenance cost estimates for each of the alternatives and sub-options under consideration. The total O&M cost of Alternative 3 and each of its constituent parts is presented in Table 3.2 below.

**Table 3.2 Alternative 3 Annual O&M Cost Summary**

<b>Item</b>	<b>Total Annual O&amp;M Cost</b>
Phase I – Reversible Lanes on High Bridge	\$650,000
Phase II – Widen Causeway and High Bridge	\$1,755,000
Improve I-880/SR 92 Interchange	\$52,000
Widen I-880 between SR 238 and SR 92	\$99,000
Improve I-880/I-238 Interchange	\$17,000
<b>SUBTOTAL</b>	<b>\$2,570,000</b>

Using the annual O&M costs summarized in Table 3.2, the 20 year net O&M costs for Alternative 3 were calculated. These costs are summarized in Table 3.3.

**Table 3.3 Alternative 3 Net O&M Cost Summary (Millions)**

<b>Improvement</b>	<b>Annual Operating Cost</b>	<b>Farebox Recovery Ratio</b>	<b>Net Annual Operating Cost</b>	<b>20-year Net Operating Cost</b>
Phase I	0.7	n/a	0.7	13.0
Phase II	1.9	n/a	1.9	38.5
<b>TOTAL ALT 2</b>	<b>2.6</b>	<b>-</b>	<b>2.6</b>	<b>51.5</b>

## **References**

- 3.1 “Precast Segmental Seismic Retrofit for the San Mateo-Hayward Bridge”, Authors: Iverson, Banchik, Brantley, & Sage; *PCI Journal*, November – December 1999, p.28-40.
- 3.2 State of California, Dept. of Transportation, Bid Summary for San Mateo Bridge Widening, (Trestle Widening), October 28, 1999.
- 3.3 State of California, Dept. of Transportation, Bid Summary for Richmond-San Rafael Bridge Seismic Retrofit Phase 3, (Trestle Replacement), August 9, 2000.

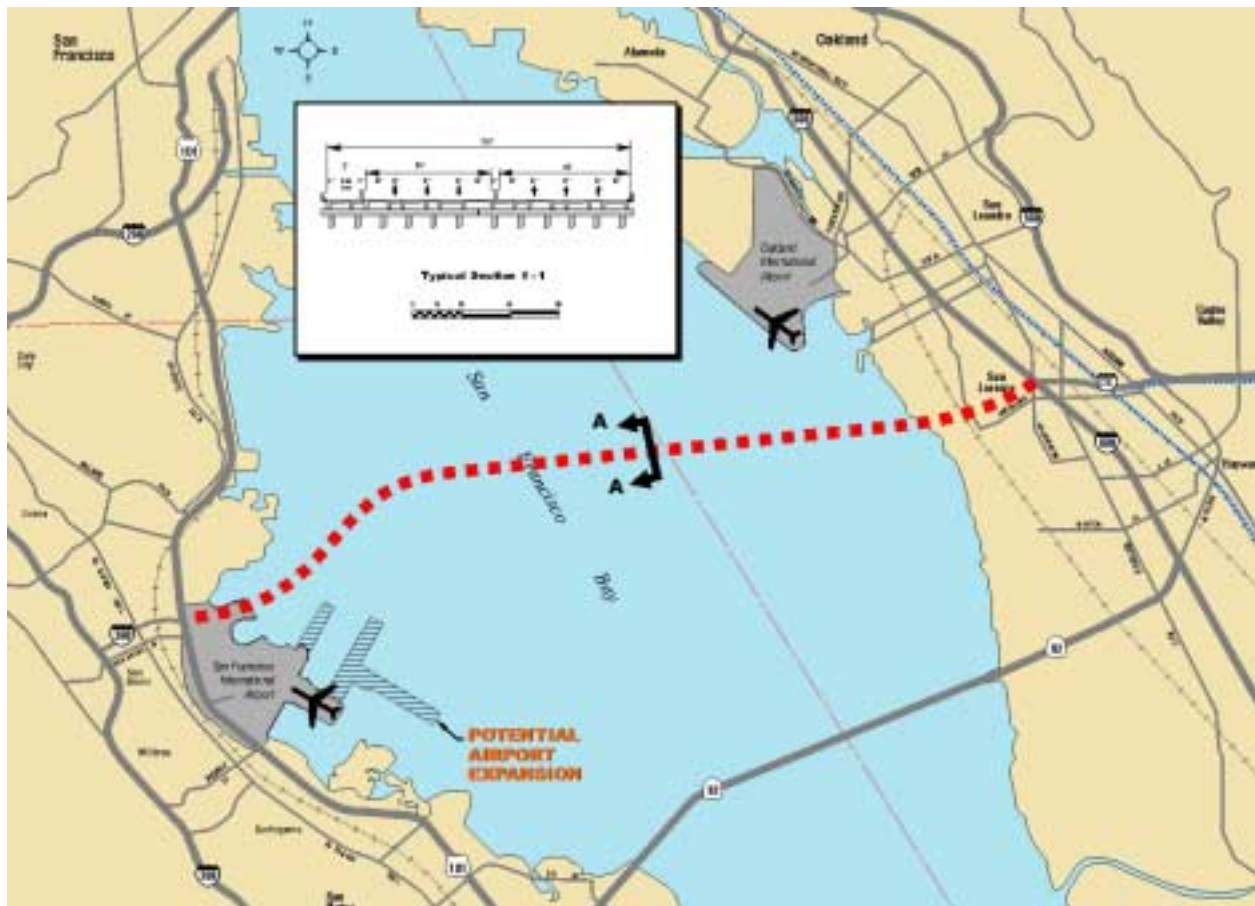
## ***ALTERNATIVE 4: NEW MID-BAY BRIDGE – I-380 TO SR 238***

### **Introduction**

This alternative consists of a new Mid-Bay Crossing connecting north of the existing San Mateo – Hayward Bridge. The proposed new crossing assumes a connection between I-380 on the west end, just north of the

San Francisco International Airport (SFO), and SR-238, which connects I-880 to I-580 in the East Bay. This alignment (shown in Figure 4.1) connects the Peninsula and the East Bay at one of the widest points of the SF Bay.

Because of the overall length of the structure, nearly 13.5 miles, the Mid-Bay Bridge will draw international attention as one of the world's longest bridges. If built, it would rank as the 6<sup>th</sup> longest, just behind Florida's Sunshine Skyway Bridge. If the main span is constructed at 850 ft as proposed, it would be the 5<sup>th</sup> longest orthotropic steel box girder span in the world. When seen in this context a new Mid-Bay Bridge would represent a major engineering undertaking.



**Figure 4.1. Overview of New Mid-Bay Bridge Alternative**

After preliminary stakeholder input was gathered at the April 3, 2002 public MTC meeting, several options to add commuter rail to the Mid-Bay crossing corridor were investigated. These included the addition of a bicycle lane and the construction of a new rail facility on or adjacent to the highway bridge. Due to time constraints, the landside connections for rail were not investigated in as much detail as the crossing itself.

## **Highway and Bike Corridor**

### ***Bay Crossing***

The crossing itself would consist of the bridge structure from the East Toll Plaza to the approaches at the I-380. The bridge can be divided into three distinct structural regions: (i) the East Causeway (trestle); (ii) the High Bridge, including the main spans over the shipping channel; and (iii) the West Causeway (trestle).

**Type:**

The low causeways on each side of the high bridge would be trestle structures similar to the existing San Mateo Bridge and the current deck replacement of the trestle for the Richmond-San Rafael Bridge, employing precast girders and driven pile supports.

Since the SFO Airport Obstruction Clearance Line is relatively low for flights in and out of the airport, we assumed the conical surface representing the airport glide path envelope crosses approximately 200-ft above MSL where the bridge alignment crosses the ship navigation channel. Because of these constraints on the channel navigation width and clearance, as well as the height limitations on the bridge, it is most likely that a long-span girder bridge would be used. The glide path will preclude any support above the deck that would project above the Obstruction Clearance. This means that a cable-stayed, suspension, or extradosed type bridge would not be acceptable alternatives for the main span structure.

The high bridge would be comprised mostly of long-span precast concrete segmental box girders, except over the main spans at the navigation channel. The main spans will have to be lightweight since a girder structure would be at the maximum span range (750-850 ft.) for this type of bridge in a high seismic region. The new Mid-Bay crossing high bridge would likely have steel box girders with an orthotropic deck similar to the existing San Mateo-Hayward Bridge, which is roughly within the same span range (750-ft). The steel box girders used in the San Mateo Bridge are haunched and have a depth at mid span of 15-ft and a depth at the piers of 30-ft. For the preliminary pricing estimate, it was therefore assumed that a similar bridge type with a girder depth of approximately 25 ft would be used. Given that midspan cannot be less than 135 ft. above the water due to the shipping channel, or more than 200 ft. in overall height due to flight obstruction clearance limits, a 25-ft deep girder would yield a structure approximately 160 ft. ( $=135+25$  ft) above MHHW.

A bike lane would add an additional 12 ft of width for the trestle and high bridge, including the main spans. The bike lane was assumed to carry emergency vehicle traffic, and therefore was estimated similarly to the vehicular bridge itself. The cost for the bike lane may decrease if load ratings are decreased resulting in a lighter structure, but only if alternate emergency access plans are also in place.

**Size:**

The East and West Causeway trestle structures would be approximately 12.1 miles long. The new high bridge was assumed to be approximately 1.1 miles long. The high bridge would incorporate a main span approximately 850 ft. long. For purposes of this study, the width of the each bridge section was assumed to be 126 ft., which includes the 8 ft. bike lane.

**Combined Highway and Rail Structure*****Bay Crossing***

One option would be to provide for rail on the new bridge. The difference between a highway and rail bridge would be that rail requires much stiffer structures than highway bridges. Hence, though the structure types may be similar to the vehicular traffic structure, the trestle, high bridge and main spans, for a rail bridge, would have much heavier and larger cross-sections than those required for carrying highway traffic.

**Type:**

The low causeways on each side of the high bridge would be trestle structures employing deep precast girders and driven pile supports. The rail loads may cause the span lengths on the trestle to be shorter than spans used on the vehicular structures.

The same height restrictions and navigation span clearances apply as previously noted. As such, a girder type structure would also be required for the high bridge and main spans.

The high bridge would be comprised mostly of long-span precast concrete segmental box girders, except over the main spans at the navigation channel. As with the trestle structure, the precast concrete spans may be considerably shorter than the vehicular spans, and the depths of the box girders used may also be deeper to accommodate rail stiffness requirements. Additional costs for foundations and structure depth were therefore considered.

The main spans would have to be as lightweight as possible while providing the required stiffness and fatigue strength for rail. A girder structure would be at the maximum span range (750-850 ft.) for this type of bridge in a high seismic region. As in Options 4A and 4B, the main spans will likely have steel girders with an orthotropic deck. In addition, to carry rail down the center of the bridge and meet the height requirements, cantilever construction techniques and design would have to be optimized. The girders will haunch and cantilever to the quarter span points of the main span from each of the two main span piers. A simple span will be supported from the cantilevers to complete the span over the navigation channel. Typical depth to span ratios for rail bridges range from 1:6 to 1:10 max. The depth of the rail girders will therefore be controlled by the simply-supported span length. For a main span of 750 to 850 ft using cantilever construction, the depth of the rail girders would be anywhere between 35 to 65 ft. deep. Though deep, these girders can be used to help separate vehicular traffic from the rail.

### *Size:*

The East and West Causeway trestle structures were assumed to be approximately 12.1 miles long. The new high bridge was assumed to be approximately 1.1 miles long. The high bridge will incorporate a main span approximately 850 ft. long. For purposes of this study, the width of the vehicular trestle portion was assumed to be 118 ft wide, while the rail trestle was assumed to be 40 ft wide. The high bridge and main span width was assumed to be 156 ft. wide to carry both rail and vehicular traffic (six lanes with full shoulders).

***Location:***

The alignment of the new Mid-Bay Bridge will cross the Bay at one of its widest points. The high bridge main span must clear the navigation channel by 135 ft above MSL. The SF Airport glide path restricts any obstruction over 200 ft. above MSL along the vehicular bridge alignment proposed.

The only alteration to the alignment proposed will be in the profile. If the vehicular and rail traffic share the same structure, the rail profile grades cannot exceed 2%. The rail and vehicular traffic would therefore climb at a different pace. The total length of the high bridge for the rail section of the bridge would therefore be slightly longer than the segments carrying vehicles, 6,750 feet long vs. 5,800 feet, respectively.

**Separate Rail Bridge**

For ease of constructability and maintenance of traffic, this option envisions that the rail and vehicular bridges are separate structures. Preliminary review of the alignment shows that a slight change of the alignment for the high rise portion of the rail bridge on the west end of the structure may yield more opportunities for connections to existing rail facilities as well as provide additional seismic safety by separating the alignments of the vehicular and rail corridors in the high bridge sections of the crossing.

The vehicular structure would be as described in the vehicular options above. The rail only structure is described in the remainder of this section.

***Location:***

The alignment of the new Mid-Bay Bridge rail corridor would be parallel and approximately 3000 ft. to the north of the vehicular bridge alignment from the East Bay. However, because of the congestion and limited landside opportunities to connect to existing rail facilities near the West touchdown for the vehicular bridge, alternative Peninsula touchdowns for the rail were examined. One of the more feasible alignments would be to connect the rail to existing facilities at Sierra Point, just north of the I-380. For purposes of this study, this was the alignment assumed for the rail only structure.

This Sierra Point touchdown alignment would have several advantages. Instead of following the curve of the vehicular alignment, it would take the rail in a shorter, more direct path toward the Sierra Point Peninsula. In this way, the rail route is moved to a less congested area away from the San Francisco Airport, while still providing accessibility to existing rail facilities and opportunities to feed commuters to Oyster Point/South San Francisco business communities/SF Airport. This alignment would provide additional seismic safety for the overall Mid-Bay transit corridor by providing redundancy.

Also, as the rail alignment moves north to Sierra Point, the SFO flight path obstruction limits become less restrictive on the overall height of the main span structure, thereby allowing a more efficient structure type to be used. The rail structure was assumed to climb at a 2% grade to clear the navigation channel. The high bridge main span must clear the navigation channel by 135 ft above MSL, similar to the vehicular bridge.

Connections for rail also then become easier. If the option with the rail on the highway bridge is pursued, the rail would have to dive under many existing highway and mass transit (BART, light rail from SFO) corridors to connect via tunnels. In comparison, the Sierra Point connections could be made with an at-grade "Y".

***Bay Crossing***

The rail crossing itself extends from the East Toll Plaza to the touchdown at Sierra Point on the West side of the Bay. The bridge itself can be divided into three distinct structural regions: (i) the East Causeway (trestle); (ii) the High Bridge, including the main spans over the shipping channel; and (iii) the West Causeway (trestle).

***Type:***

The low causeways on each side of the high bridge would be trestle structures employing deep precast concrete trestle and driven pile supports. Because rail loads are much heavier than vehicular traffic and because rail specifications tend to require stiffer structures, the rail trestle structures will be comprised of larger sections and shorter spans than the vehicular bridge.

The high bridge type is constrained by similar clearance and height limitations as the vehicular high bridge. It must maintain a 700-850 ft main span and clear height of 135 ft above the shipping channel, as well as remain clear from obstructions (supports), which protrude above the deck due to its proximity to San Francisco International Airport. With the revised rail alignment described above, it is possible to move the high bridge over the navigation channel to a region where the air space obstruction envelope increases to approx. 350 feet. The best structure type, which meets these criteria, is a steel truss deck or steel through-truss bridge structure.

### *Size*

The total length of trestle structure was assumed to be approximately 9.9 miles long. The new high bridge was assumed to be approximately 1.3 miles long. The high bridge would incorporate a main span approximately 850 ft. long. The total length of the proposed rail bridge alignment would be approximately 11.2 miles, as compared to the 13.2 miles for the alignment proposed in Option 4C. For purposes of this study, the width of the each bridge section was assumed to be 48 ft.

### **Potential “Recycled” Rail Only Structure**

While the study has not forecasted significant transit ridership for a new Mid-Bay crossing and there would be operational issues associated with connecting to BART or Caltrain on the Peninsula, a unique opportunity would exist to re-use and “recycle” an existing steel truss bridge for a new Mid-Bay rail corridor. The current East Span of the San Francisco-Oakland Bay Bridge (SFOBB) will be de-commissioned soon, as a replacement bridge has been designed and will soon be under construction. The seismic safety issues surrounding it have to do with the foundations and the articulation of the overall bridge (where and how the bridge is allowed to move). The SFOBB steel trusses have been carefully maintained as part of the California Toll Bridge system, and in recent years many of the steel members have undergone further seismic strengthening.

The current demolition plan for SFOBB includes the cost of removing and transporting the bridge from its current piers and foundations, thereby being very cost-effective if re-used for the rail corridor on a new Mid-Bay Crossing. Thus, the cost for a new rail bridge would be greatly minimized; only costs to construct new foundations, new causeway trestle structures, and trackwork and systems would be required.

### **East Bay Highway Interchanges and Approaches from SR-238**

SR-238 is currently considered a “lifeline” for vehicular traffic and cargo-carrying trucks between I-580 and I-880. As such, interchanges, ramps, and structures comprising SR-238 must perform to a higher level of service following a major seismic event. SR-238 is further impacted by its proximity to the Hayward Fault. Parts of the route cross the Hayward Fault, where fault rupture must be considered in the seismic performance and structural design. The suggested improvements for the Bay Crossings Study as they relate to SR-238 must also consider some of these design parameters. It is suggested that any improvements consider low viaducts and depressed roadways or short tunnelized roadways, as these types of structures respond with the ground and tend to be less vulnerable to large seismic events and the large displacements associated with fault ruptures.

East Bay Approach improvements include two major regions of impact:

- Region 1: Eastern Bridge Approach;
- Region 2: SR-238 and I-880 Interchange Improvements

Major items for Region 1 include:

- Toll Plaza including bike access
- Vent buildings
- Freeway tunnel twin bores, each 3-lanes 46-ft diameter with cross-passages
- Cut and cover transition boxes, 6 lanes
- Cut and cover boxes, 2 lane ramps
- Retained open cuts
- Underground easements

Major Items for Region 2 include:

- Elevated Ramp Structures (40 ft. wide/1 lane)
- Freeway Tunnel Twin Bores, each 3-lanes 46-ft diameter with cross-passages
- At-grade lanes (40' wide)
- Bridge Widening (20' wide)
- ROW including single family home acquisitions
- Underground Easements

### **Peninsula Highway Interchanges and Approaches to I-380**

Peninsula Approach major improvements include:

- Aerial Freeway (126' wide)
- Aerial Ramp (24' wide/1 lane)
- Aerial Ramp (36' wide/2 lanes)
- At-grade ramp (24' wide/1 lane)
- ROW including single family home acquisitions

### **East Bay and Peninsula Rail Connections**

Major improvements for rail connections include:

- Vent Shafts
- Rail Tunnel twin bore each 40-ft diameter with cross-passages at 1200 ft. with Y branch
- At grade Y at Sierra Point
- Underground Easements
- ROW Acquisitions including single family home acquisitions.

### **New Mid-Bay Bridge Vehicular and Rail Corridor Cost Elements**

Costs for constructing vehicular trestle were based on current Bay Area trestle contracts under construction. Bid documents were reviewed for the Richmond San Rafael trestle replacement project and the current San Mateo Bridge trestle widening. These projects were considered to be very good indicators for costs given proximity of the locations of each project relative to this alternative as well as the type and scope of construction undertaken.

Costs for estimating the high bridge carry slightly more risk than the trestle portion of the structure. This is caused by several mitigating factors. The high bridge, while predominantly precast segmental concrete, includes a portion of steel on the main spans. Steel bridge structures have not been constructed in the Bay Area since the existing San Mateo Bridge was built in the 1960's. The main spans of the new Bay Bridge East Spans have been designed using steel; however bids for construction have not yet been tendered. The outcome of this project may greatly influence the price for steel structures on this widening alternative. Another challenge for this project is the complex issue of schedule and fabrication of large steel structure in the US. Procurement from other countries such as China and Japan is complicated by current market trends.

The Approach Improvements carry higher project contingencies than the crossing itself due to larger impacts to traffic and landside disruption. Unlike the crossing itself, the associated unknowns with construction, environmental remediation, and traffic re-routing during construction are greater and therefore carry a much higher risk for the project as a whole. These risks and the contingencies associated with them typically tend to decrease as the scope of the project is better defined and impacts are more accurately established and weighted. As the goal of the project was to capture the order of magnitude costs of improvements, Caltrans cost data was used to quickly estimate the approach improvement items.

## **Capital Cost Estimate Summary**

Appendix 0A presents detailed capital cost estimates for each of the alternatives and sub-options under consideration. The total project cost of Alternative 4 and each of its constituent parts is presented in Table 4.1 below. As previously discussed, high end and low end capital cost estimates have been prepared. Table 4.1 summarizes this cost range.

**Table 4.1 Alternative 4 Capital Cost Summary**

<b>Item</b>	<b>Total Capital Cost</b>
<b>High-Range Estimate</b>	
Crossing	\$3,590,000,000
Approach	\$4,428,000,000
ROW	\$207,000,000
Rolling Stock (Buses)	\$20,000,000
<b>SUBTOTAL</b>	<b>\$8,245,000,000</b>
<b>Low-Range Estimate</b>	
Crossing	\$3,165,000,000
Approach	\$3,254,000,000
ROW	\$207,000,000
Rolling Stock (Buses)	\$20,000,000
<b>SUBTOTAL</b>	<b>\$6,646,000,000</b>

## **Operations and Maintenance Cost Estimate Summary**

Appendix 0B presents detailed operations and maintenance cost estimates for each of the alternatives and sub-options under consideration. The O&M cost of Alternative 4 and each of its constituent parts is presented in Table 4.2 below.

**Table 4.2 Alternative 4 Annual O&M Cost Summary**

<b>Item</b>	<b>Total Annual O&amp;M Cost</b>
3.2 New Mid Bay Bridge Highway Improvements	\$17,400,000
3.2 Mid Bay Bridge Express Bus Service	\$17,600,000
<b>TOTAL ALTERNATIVE 4 ANNUAL O&amp;M COST</b>	<b>\$35,000,000</b>

Using the annual O&M costs summarized in Table 4.2 along with anticipated farebox recovery ratios, the 20 year net O&M costs for alternative 4 were calculated. These costs are summarized in Table 4.3.

**Table 4.3 Alternative 4 Net O&M Cost Summary (Millions)**

<b>Improvement</b>	<b>Annual Operating Cost</b>	<b>Farebox Recovery Ratio</b>	<b>Net Annual Operating Cost</b>	<b>20-year Net Operating Cost</b>
Highway Improvements	\$17.6	n/a	\$17.6	\$352.4
Express Bus	\$17.4	50%	\$8.7	\$174.1
<b>TOTAL ALT 2</b>	<b>\$35.0</b>	<b>-</b>	<b>\$26.3</b>	<b>\$526.5</b>

### **Other Capital Cost Items**

As previously discussed, a number of other costs in this corridor have been calculated. These include the cost of installing rail on the highway bridge and alternatively, constructing a new rail crossing adjacent to the highway bridge. These rail costs do not include stations or rolling stock, nor has an operating plan been identified. The portion of the new bridge costs that would be incurred as the result of the addition of a bike lane to the bridge have also been isolated. These costs are as follows:

- Cost Addition due to Bike Lane - \$341,000,000;
- Rail Bridge Adjacent to Highway Bridge - \$4.9 to \$6.5 Billion; and
- Rail Bridge on Highway Bridge - \$11.9 Billion.

## ***ALTERNATIVE 5: DUMBARTON RAIL BRIDGE***

### **Augmentation of Current Studies**

San Mateo County Transportation Authority has commissioned several studies evaluating alternative improvements to the Dumbarton Rail Corridor (Ref 1, 2 3) including the bridge repair and cost of new service. These conceptual studies were used to develop the base cost estimate. However, this past work did not advance to the level of detail that would allow for screening of seismic vulnerabilities. The study team has been informed that this screening work is under way as part of the effort to update the project cost derived in 1999.

### ***Seismic Allowance***

Since the 1999 study, the liquefaction susceptibility of the soils in the area of the corridor has been better defined and recorded in the USGS Open File Report 00-44. The report indicates that the susceptibility is high.

A key consideration for the potential retrofit will be ground displacement. Soil that is highly susceptible to liquefaction carries the risk of flowing towards the relatively deeper navigation channel. As a result the guideway carries the risk of permanent lateral and vertical dislocation. Strategies to mitigate this adverse impact

will be the focus of the EIR/EIS phase of project development. As a result, it is considered prudent at this stage to make an allowance for the potential of seismic retrofit for the grade-separated rail link as well as the at grade rail link.



**Figure 5.1. Overview of Dumbarton Rail Corridor Improvements**

### **Operating Plans**

The San Mateo County Transportation Authority has developed a basic plan for initial service implementation (Ref 3). Capital and operating cost estimates have been developed by others for this basic service plan. These estimates have been incorporated into the Bay Crossings Study, with an allowance added for seismic strengthening of the rail bridge. A summary of these estimates are attached in Appendix 5A. The basic service plan would run three trains from Union City to San Jose and three trains from Union City to Millbrae in the morning peak period. These six trains would also provide the reverse service during the evening peak period.

In addition to the basic service plan, an expanded service plan was developed and evaluated as part of the study. This expanded service plan adds three trains from Tracy to Millbrae and three trains from Tracy to San Jose to the basic service plan in the morning peak period. In addition, reverse direction trains would be run from Millbrae to Union City and San Jose to Union City in the morning peak period. This service plan expansion would be reversed in the evening peak period.

### **Capital Cost Estimate Summary**

Appendix 0A presents detailed capital cost estimates for each of the alternatives and sub-options under consideration. Capital cost estimates are presented in Table 5.1 for the basic service plan. These estimates include the rehabilitation of the damaged rail bridge, purchase of rolling stock and various East Bay track improvements. It should be noted that the East Bay track improvements included in the estimate would benefit many other services, namely the Capitol Corridor and ACE, and the costs of the improvements could also be borne by multiple services.

**Table 5.1 Alternative 5 Capital Cost Summary – Basic Service Plan**

<b>Item</b>	<b>Total Capital Cost</b>
Rehabilitation of Damaged Bridge, Rolling Stock, Track Improvements	\$130,000,000
Seismic Allowance	\$50,000,000
<b>TOTAL</b>	<b>\$180,000,000</b>

Table 5.2 presents the capital cost summary for the expanded service plan. This plan includes additional East Bay track improvements and service from Tracy.

**Table 5.2 Alternative 5 Total Capital Cost Summary with Expanded Service Plan**

<b>Item</b>	<b>Total Capital Cost</b>
Basic Service with Seismic Allowance	\$180,000,000
East Bay Track Improvements	\$21,600,000
Additional Rolling Stock	\$86,900,000
<b>TOTAL</b>	<b>\$288,500,000</b>

### **Operations and Maintenance Cost Estimate Summary**

Appendix 0B presents detailed operations and maintenance cost estimates for each of the alternatives and sub-options under consideration. The O&M cost of Alternative 5, both the basic and expanded service plans, are presented in Table 5.3 below.

**Table 5.3 Alternative 5 Annual O&M Cost Summary**

<b>Item</b>	<b>Total Annual O&amp;M Cost</b>
Basic Service Plan	\$5,300,000
Expanded Service Plan	\$23,000,000

Using the annual O&M costs summarized in Table 5.3 along with anticipated farebox recovery ratios, the 20 year net O&M costs for Alternative 5 were calculated. These costs are summarized in Table 5.4.

**Table 5.4 Alternative 5 Net O&M Cost Summary (Millions)**

<b>Improvement</b>	<b>Annual Operating Cost</b>	<b>Farebox Recovery Ratio</b>	<b>Net Annual Operating Cost</b>	<b>20-year Net Operating Cost</b>
Basic Service Plan	\$5.3	38%	\$3.3	\$65.3
Expanded Service Plan	\$23.0	38%	\$14.2	\$283.7

References:

1. Dumbarton Rail Corridor Study, prepared by Parsons Brinckerhoff Quade & Douglas, 1997.
2. Dumbarton Rail Corridor Rehabilitation, Preliminary Design, prepared by MK Centennial, 1997.
3. Dumbarton Rail Corridor Study Service Plan Evaluations, prepared by De Leuw Cather, Steinman, July 1999.

***ALTERNATIVE 6: DUMBARTON BRIDGE CORRIDOR HIGHWAY IMPROVEMENTS***

**Purpose**

The purpose of this alternative is to provide a dedicated new approach road connection between US 101 and the Dumbarton Bridge to improve utilization of the Dumbarton Bridge as well as create a more balanced distribution of traffic on local roadways (University Avenue & Bay Front Expressway).

***Segments/Definition:***

For the purposes of cost estimating, the corridor has been separated into three segments. Segment 1 extends from the northern connection with SR 84 to south of the railroad tracks. Segment 2 extends from south of the railroad tracks to north of the San Francisquito Creek and Segment 3 extends from the San Francisquito Creek to US 101. A number of construction options have been identified for each section. These options are summarized briefly below.

Segment 1:

- (a) Bored tunnel; or
- (b) Grade Separate SR 84/University Avenue, at-grade roadway north of railroad and bridge over railroad.

Segment 2:

- (a) Depressed at-grade roadway.

Segment 3:

- (a) Bored tunnel; or
- (b) Bridge over Creek, retained open cut roadway and jacked tunnels.

**Type:**

The improvement types considered to have the greatest impact on cost were the grade-separated alternatives which included the:

- Grade separated crossing of the salt-flats/wetlands on northern end of corridor;
- Grade separated RR crossing;
- Crossing of San Francisquito Creek;
- Grade separated crossing of US 101; and
- Grade separated crossing of Oregon Expressway & Embarcadero Road connections to US 101.

Both aerial and subterranean grade separations were considered. Table 6.1 summarizes the alternatives considered. In order to capture the complexity of the corridor the base case estimate was based on Alternative Type-1.

**Table 6.1: Grade Separation Alternatives Considered**

<i>Feature Crossed</i>	<i>Alt. Type-1 Lowest Cost</i>	<i>Alt. Type-2 Highest Cost</i>	<i>Alt. Type-3 Most Site Impact</i>
Northern Wetlands	Separation Structure	Bored Tunnel	
Railroad	Separation Structure	At Grade	-
Creek	Aerial	Bored Tunnel	Jacked Tunnel
US 101	Jacked Tunnel	Bored Tunnel	Aerial
Oregon/Embarcadero	Depressed Open Cut with Slab Bridge at cross streets	Bored Tunnel	Cut & Cover

**Size:**

- 4-Lane at Grade Facility
  - Separation structure
- 2-Lane Grade Separated Facility
  - Bored Tunnel Option: Two bores approximately 36-ft in diameter (1-lane each with shoulders, vent space, drainage gallery and emergency egress)
  - Open Cut Depressed Roadway Options: Inside to Inside width approximately 54-ft (2 lanes, median with barrier, side shoulders, drainage gallery and emergency egress)
  - Jacked Tunnel: Inside to inside approximately 25-ft (1 lane, vent space, side shoulders, drainage gallery)

**Location:**

The transportation analysis indicated that a likely corridor would run north to south from the Dumbarton Bridge Approach and intercept US101 in the vicinity of Greer Park near Colorado Ave. Phase 1 would comprise the length from the bridge approach to Bay Road in East Palo Alto and Phase 2 would extend the corridor to connect to US 101.

This north/south connection was located primarily along the eastern edge of the Grant Boundary (bordering the Bay) of East Palo Alto and, upon crossing San Francisquito Creek into Palo Alto, the alignment skirts the Municipal Golf Course traversing a freeway side business development (See Figure 6.1).



**Figure 6.1. Overview of Dumbarton Bridge Corridor Highway Improvements**

The soils in this area are highly susceptible to liquefaction. That is, they can be characterized as loose and in an area where the water table is high. It is expected that these characteristics will have the following consequences;

- Bridge foundations will need to be stiff;
- Water cut-offs in the form of tremie-seals or jet-grout bottom's will be likely in order to construct bridge foundations and open cuts;
- Slurry walls are likely needed to construct open cuts and control ground water inflows; and
- Ground freezing is likely needed for tunnel jacking.

### ***Future Work***

While this study has captured the scope of this connection it has not provided a definitive design solution. The study team understands that the local jurisdictions are undertaking more detailed studies to develop alternatives which best meet a variety of transportation, environmental and social justice concerns.

Given that the tolerance for surface disruption in this congested area is low it is recommended that bored tunnels be given serious consideration.

### **Capital Cost Estimate Summary**

Appendix 0A presents detailed capital cost estimates for each of the alternatives and sub-options under consideration. Preliminary capital cost estimates are presented in Table 6.3 for Alternative 6. As discussed above, substantial additional study is necessary to refine an alignment and construction technology for this alternative. The estimate summarized in Table 6.3 presents cost ranges for each of the construction approaches and technologies currently under consideration. Environmental mitigation costs are not included in the estimate.

**Table 6.3 Alternative 6 Capital Cost Summary**

<b>Item</b>	<b>Total Capital Cost Range</b>
Segment 1	\$142,500,000 to \$1,056,900,000
Segment 2	\$61,900,000 to \$72,300,000
Segment 3	\$469,000,000 to \$761,600,000
<b>TOTAL</b>	<b>\$673,400,000 to \$1,890,800,000</b>

### **Operations and Maintenance Cost Estimate Summary**

Appendix 0B presents detailed operations and maintenance cost estimates for each of the alternatives and sub-options under consideration. The O&M cost of Alternative 6 is presented in Table 6.4 below.

**Table 6.4 Alternative 5 Annual O&M Cost Summary**

<b>Item</b>	<b>Total Annual O&amp;M Cost</b>
Total Annual O&M Cost Alternative 6	\$135,000

Using the annual O&M costs summarized in Table 6.4 the 20 year net O&M costs for alternative 6 were calculated. These costs are summarized in Table 6.5.

**Table 6.5 Alternative 6 Net O&M Cost Summary (Millions)**

<b>Improvement</b>	<b>Annual Operating Cost</b>	<b>Farebox Recovery Ratio</b>	<b>Net Annual Operating Cost</b>	<b>20-year Net Operating Cost</b>
Alternative 6	0.14	-	0.14	2.7

## ***SUMMARY OF ALTERNATIVE COSTS***

The table below summarizes the capital and operating costs of the six alternative packages.

### **Summary of Capital Costs**

<b>Alternative Package</b>	<b>Total Capital Cost</b>
1 – Express Bus/HOV/Operational Improvements	\$653,000,000
2 – Bay Bridge Corridor Rail - BART	\$7,100,000,000 to \$10,270,000,000
2 – Bay Bridge Corridor Rail – CONVENTIONAL RAIL	\$7,490,000,000 to \$11,770,000,000
3 – San Mateo/Hayward Bridge Corridor Improvements	\$2,052,000,000 to \$2,356,000,000
4 – New Mid-Bay Bridge	\$6,646,000,000 to \$8,245,000,000
5 – Dumbarton Rail Bridge – Basic Service Plan	\$180,000,000
5 – Dumbarton Rail Bridge – Expanded Service Plan	\$288,500,000
6 – Dumbarton Bridge Corridor Highway Improvements	\$673,400,000 to \$1,890,800,000

### **Summary of Annual Operating Costs**

<b>Alternative Package</b>	<b>Total Annual Operating Cost</b>
1 – Express Bus/HOV/Operational Improvements	\$54,000,000
2 – Bay Bridge Corridor Rail - BART	\$133,640,000
2 – Bay Bridge Corridor Rail – CONVENTIONAL RAIL	\$18,100,000
3 – San Mateo/Hayward Bridge Corridor Improvements	\$2,570,000
4 – New Mid-Bay Bridge	\$35,000,000
5 – Dumbarton Rail Bridge – Basic Service Plan	\$5,300,000
5 – Dumbarton Rail Bridge – Expanded Service Plan	\$23,000,000
6 – Dumbarton Bridge Corridor Highway Improvements	\$135,000

### **Summary of 20-Year Net Operating Costs**

<b>Alternative Package</b>	<b>20-Year Operating Cost</b>
1 – Express Bus/HOV/Operational Improvements	\$531,900,000
2 – Bay Bridge Corridor Rail - BART	\$1,132,700,000
2 – Bay Bridge Corridor Rail – CONVENTIONAL RAIL	\$222,600,000
3 – San Mateo/Hayward Bridge Corridor Improvements	\$51,500,000
4 – New Mid-Bay Bridge	\$526,500,000
5 – Dumbarton Rail Bridge – Basic Service Plan	\$65,300,000
5 – Dumbarton Rail Bridge – Expanded Service Plan	\$283,700,000
6 – Dumbarton Bridge Corridor Highway Improvements	\$2,700,000

## Appendix 0A:

Capital Cost Calculation Worksheets

## Appendix 0B:

Operational Cost Calculation Worksheets

## Appendix 1A:

Express Bus Service Summary

## Appendix 1B:

BART Operations and Maintenance Cost Analysis Summary

## Appendix 2A:

A draft of this BART Break-out and branch line report was reviewed and commented on by MTC and BART panel members. The Break-out's were deemed to be difficult to implement.

### **Introduction**

The purpose of this study is to explore the feasibility and prudence of extending branch lines from the existing BART mainline in the City of San Francisco.

The following are the branch line candidate corridors that were investigated in this study:

- South of Market Lines
  - Mission Street
  - Howard Street
- North of Market Lines
  - Geary Street
- Market Street (Expand from two BART Tracks to four)

### ***Relationship between Branch Lines and Breakouts***

A branch line requires a breakout from the mainline. As a result the feasibility of the branch line is largely determined by the feasibility of the constructing the breakout.

It is assumed that the breakout would conform to BART geometric and trackwork criteria as well as minimize impacts to BART operations during breakout construction.

### ***Branch Line Corridors***

Schematics for the corridors considered are shown on Figures 1 through 3.

These figures show the branch lines originating from what is the most feasible breakout point which is between Steuart Street (just east of the MUNI Turnaround crossover) and Trans Bay Tube (TBT) No. 58 (connecting the existing bored tunnel to the SF Vent Building).

An offshore breakout at Yerba Buena Island was also considered. The potential benefits of greater surface access were offset by the disturbance to the bay (Navigation & Resource), the considerable risk of TBT shutdown and finally the adverse impact to seismic performance.

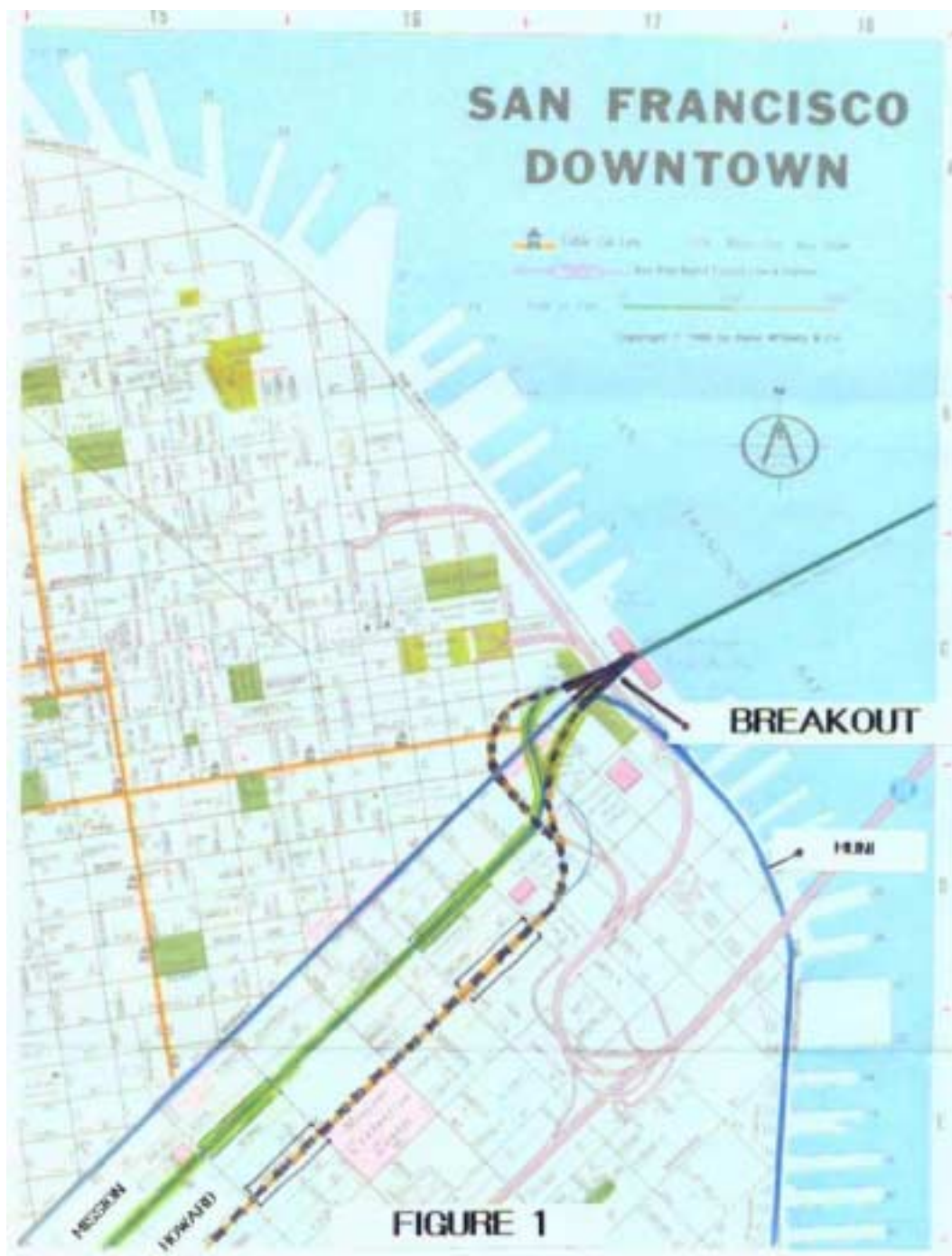
### ***Note on Contents***

This document first examines the feasibility of constructing a breakout, because without a breakout there would be no branch line. This discussion is followed by a brief review of the corridors and then finally by the conclusions.

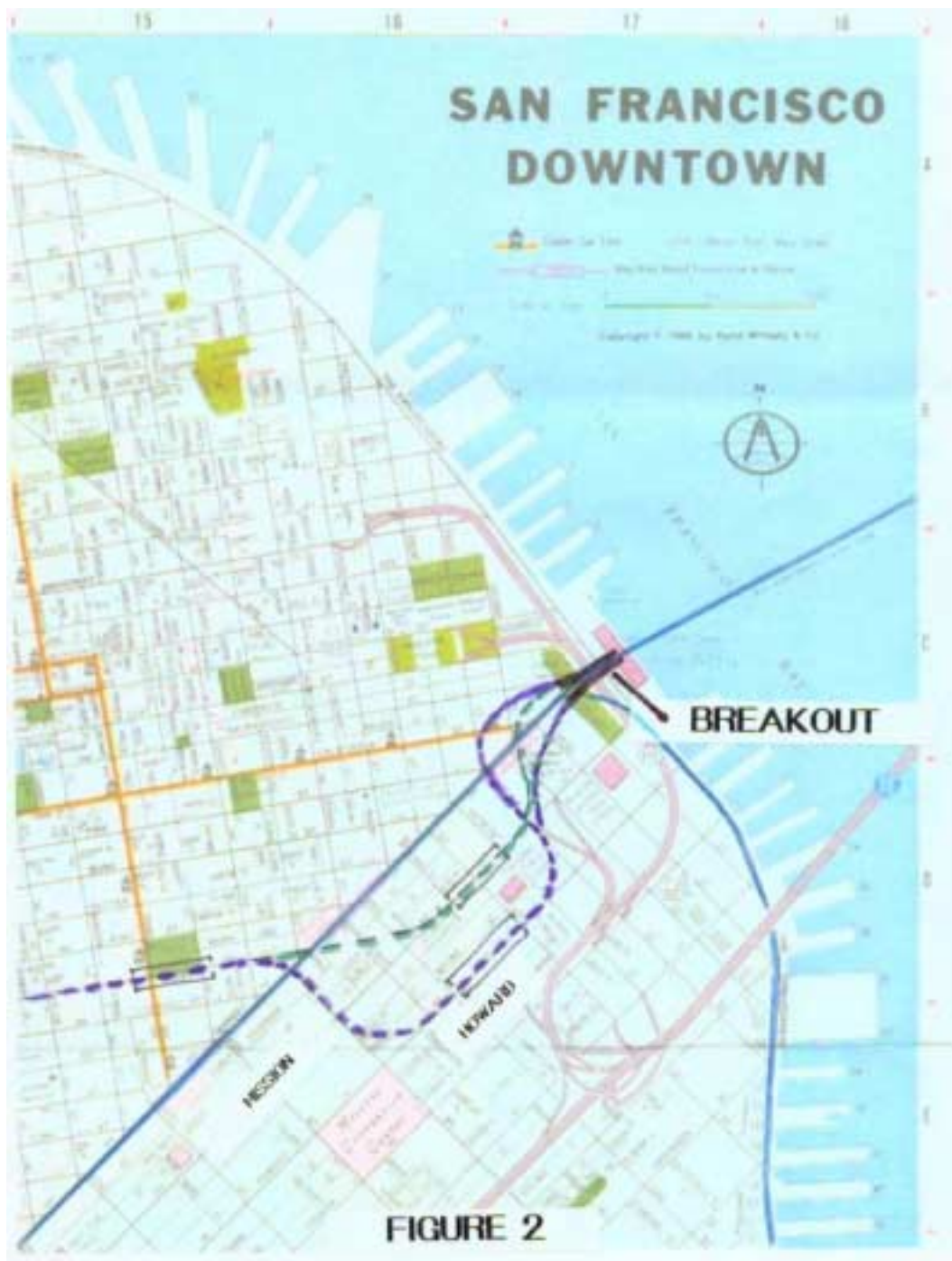
### **Feasibility of the Breakout**

The breakout concept calls for relieving the external ground loads on the existing steel plate tunnel lining. Load relief can be provided by using some form of external shoring or supplemental support.

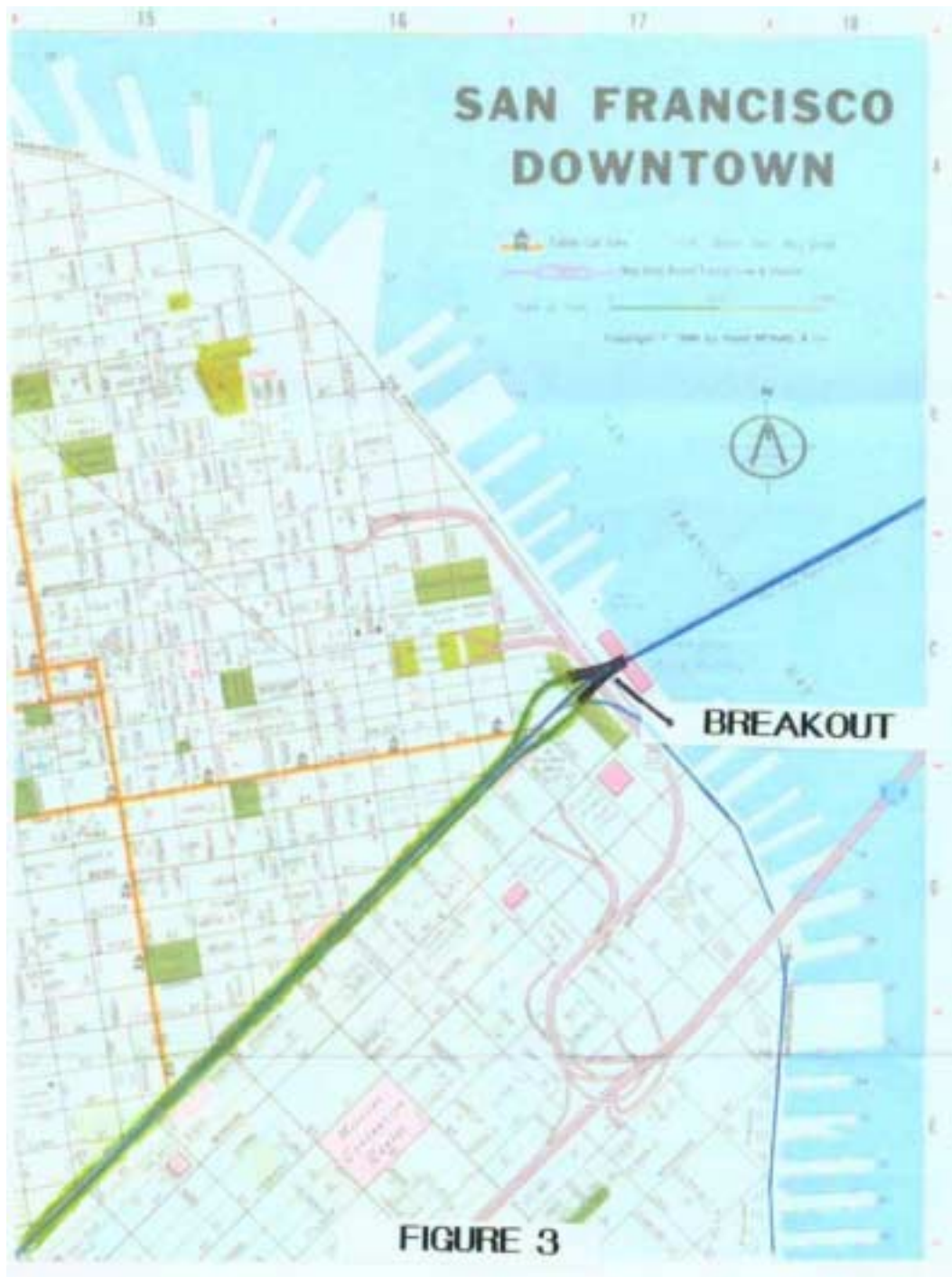
One concept for providing the necessary shoring or external support is to build the tunnels that make up the transition to the branch line within a structural diaphragm wall. Once the external ground loads are relieved the opening or breakout of the existing tunnel lining can be carried safely.



**SOUTH OF MARKET BRANCH LINES**

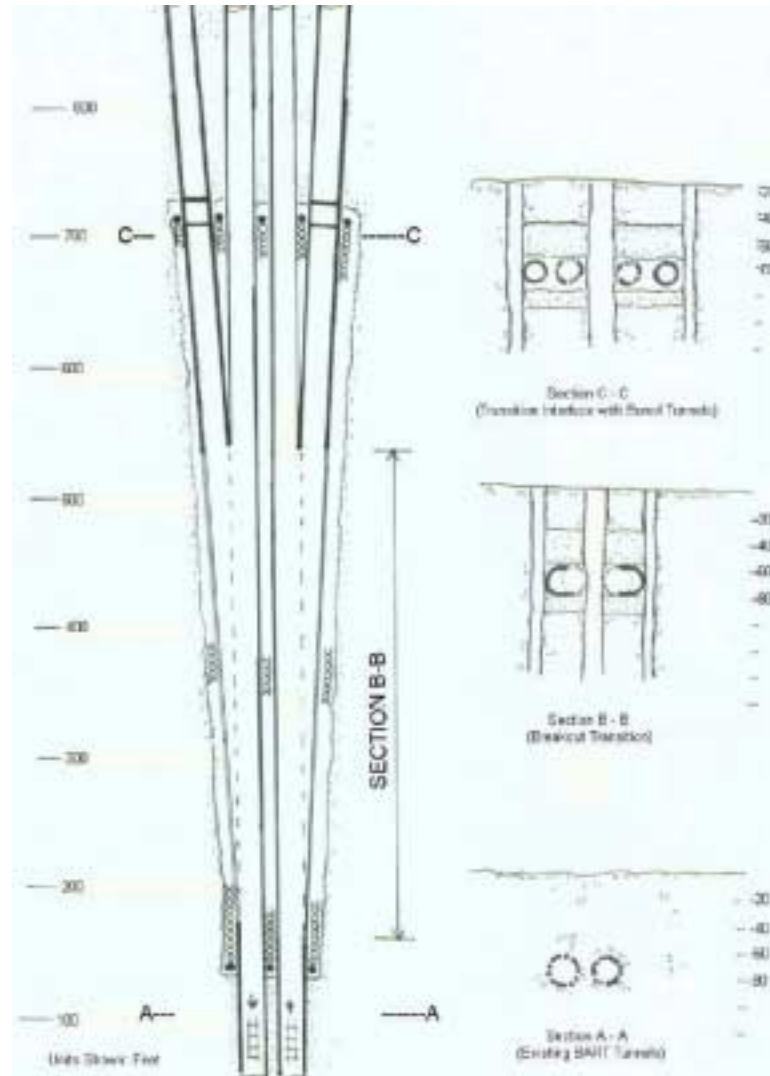


NORTH OF MARKET BRANCH LINES



MARKET STREET EXPANSION LINES

Supplementing the diaphragm walls would be some form of ground improvement (e.g. jet grouting), which would be required to strengthen and stiffen the soil and to control ground water. This improvement would be confined by structural supports such as closely spaced pilings (installed directly adjacent or tangent to one another or installed with some overlap or “secant” arrangement) or slurry walls.



**FIGURE 4. BREAKOUT CONCEPT FOR BORED BRANCH LINES**

Since the existing material is saturated, it is expected that the confined transition area would be dewatered. As a result, water cut-offs made by ground improvements below the existing tunnels would be required. Ground improvements and wall construction would require surface construction access and result in significant surface disruption.

The size of the breakout will be a function of:

- Constructability
- Access from above to implement ground improvements
- Operation clearances
- Turnout switch geometry (Turnout No. 15 for 35 mph design speed; Turnout No. 20 for 40 mph).

The existing mainline clearances between the vehicle and the liner are the minimum allowable and resulted in an efficient tunnel cross-section. A branch line was never envisioned, and as a result, liner modifications are needed at each breakout from the mainline.

Branch line transition length estimates considered the sum of the actual leads and crossovers meeting the criteria for mainline switch geometry (Turnout nos. 15 and 20). The transition lengths range from 180 to 220 feet. The flatness of the switch (frog) angle results in a minimal clearance between the main and branch line bores outside the transition zone, which was too close to facilitate Tunnel Boring Machine operations.

As a result the gap between the main and branch line tunnel bores have to be widened. A likely gap between bores is expected to be around 10 feet. The resulting length of this special transition was then estimated to be in the range of 550 to 650 feet. Shown below (Figure 4) is the transition using a Turnout No. 20.

In order to minimize BART impacts, access to this confined transition area could be achieved through the bored branch line tunnels (Section C-C). The confined transition area would then be excavated by "hand".

Special transition liners would then be installed (see Section B-B in Figure 4, for Bored Alternative), followed by track work and electrification.

### **Candidate Breakout Locations**

- Bored Branch Line Tunnel (BBT):
  - Within the 1400-ft run between Trans Bay Tube (TBT), Tube 58 (west of vent shaft) and the Spear Street vent shaft
  - Market Street Corridor (Originating between TBT and Spear Street)
- Immersed Tube Branch Line Tunnel (ITT)
  - Yerba Buena Island (YBI)
  - Market Street Corridor (Originating from YBI)

### ***Bored Branch Line Breakout***

The Bored Branch Line (BBL) breakout options are hampered by the fact that the existing BART tunnels are relatively shallow. With inverts approximately 75 feet below grade, the breakouts would be shallow and not allow the branching BART tunnels to reach the depths needed to reduce surface disruption (impacts on existing building foundations, utilities and surface street functions) to levels where practical mitigation is possible. Note that deeper breakouts will not lessen surface impact since they would require deeper diaphragm walls.

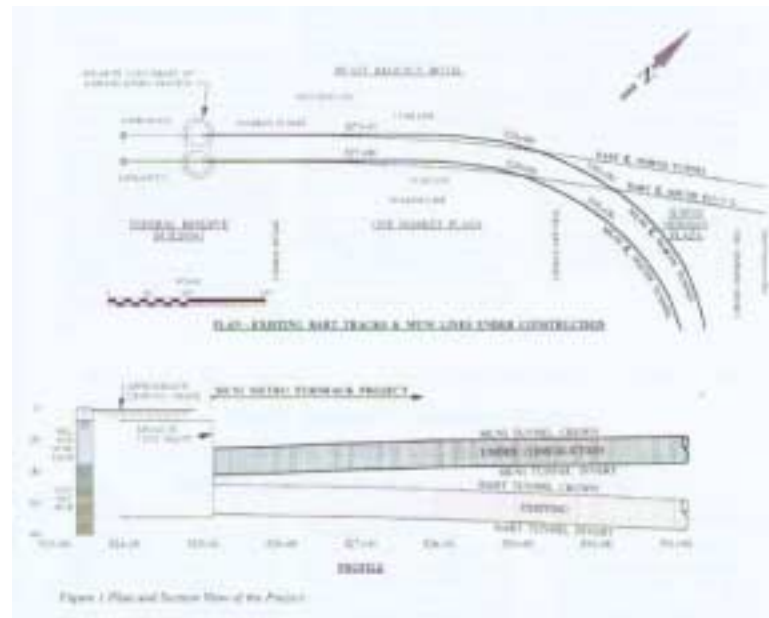
The least undesirable location for the breakout when considering subsurface constraints is just east of the MUNI Turnaround. The Ferry Building, as well as the foot of Market Street will be significantly impacted by operations to improve the ground in order to make the breakout.

The Ferry Building, which is currently undergoing seismic retrofitting, would have to be temporarily modified to allow the ground improvement operations to take place. Underpinning is expected.

Traffic on Market Street, MUNI "F" Line operations, access to the new Ferry Landing (currently under construction and located just south of the Ferry Building) and the seawall would also be adversely impacted.

In order to avoid these impacts, an alternate breakout nearer to the Spear Street vent shaft was considered and found not feasible mainly because shoring and ground improvements in this area are complicated by the presence of the MUNI Turnaround that runs above BART between Steuart and Spear Streets (see Figure 5).

Compounding the difficulties is the fact that the original BART construction relocated the utilities to run on either side of the Market Street MUNI/BART tunnels.



**FIGURE 5. MUNI TURNAROUND**

### *Immersed Tube Branch Line Breakout*

The next step was to look offshore, where less congestion offered some promise. Conceptually the best place for a breakout in the existing Trans Bay Tube was determined to be near Yerba Buena Island.

At this location the tube is relatively shallow where the TBT rises over the underground YBI rock ridge. Construction operations for the Immersed Tube Branch Line Tunnel breakout would amount to creation of a cofferdam in order to uncover at least two segments of the existing tube. The cofferdam potentially could remain as a permanent man-made island.

Moving the breakout further east only serves to undermine the branch line concept since the result would be in effect a second bay crossing that is saddled with the undesirable features associated with the ITT breakout.

### *Impact of Breakout on Seismic Performance*

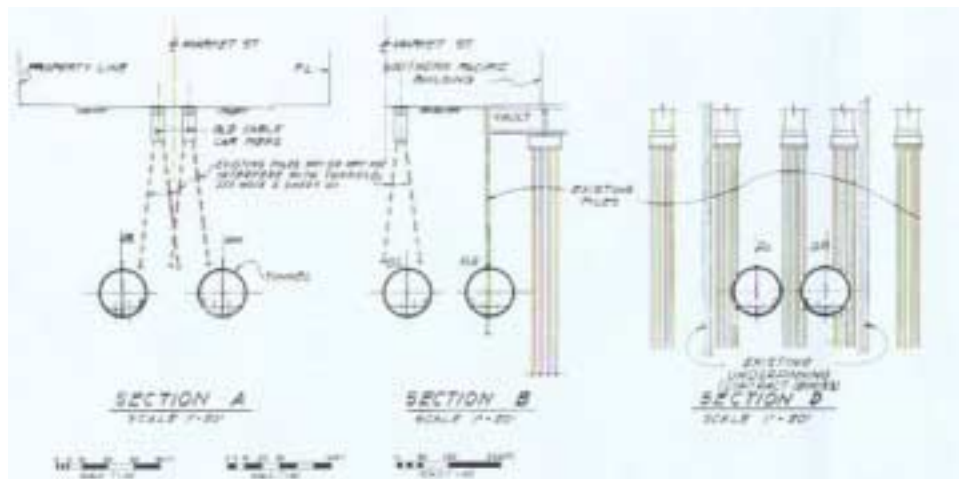
The breakouts, especially in the case of the ITT, stiffen the tunnels locally. As a result the seismic response of the tunnel could be adversely affected by these new “hard-points” unless appropriate measures to maintain flexibility were implemented.

In the original design this key issue was tackled and subsequently resolved by the creation of multi-degree of freedom movement joints between the tube and the vent buildings.

### **Feasibility of Branch Line Corridor Construction**

To put this issue into perspective, it is useful to look back at the original BART construction where, “over 20 miles of subway construction were completed with only two major underpinning jobs and without a significant claim for major damage to adjacent structures”<sup>1</sup>.

One of the major underpinning jobs was for the Ferry Building. Protection of this low-rise structure facilitated the construction of the TBT approach tunnel, between the Spear Street vent shaft and the TBT vent shaft (see Figure 6). This was a major achievement, considering that in San Francisco the tunnels were driven beneath congested streets through some of “the worst geological conditions in the city an area of soft mud that had been filled during Gold Rush days, and which was littered with buried remains of sunken ships, debris from the 1906 earthquake, and the remains of old cable car railways”<sup>1</sup>.



**FIGURE 6.**  
**TYPICAL SECTION OF EXISTING BART TUNNELS IN VICINITY OF BREAKOUT**  
**(SECTION D SHOWS THE UNDERPINNING OF THE FERRY BUILDING)**

Since the original BART construction, the character of the downtown has changed. Today the skyline is dominated by high-rise buildings, most of which are located in the reclaimed land that extends downtown to the east.

BART was successfully constructed because the property owners were exposed to relatively low risk of damage to their buildings and parcels. The scenarios considered for creating branch lines must attempt to adopt this key feature, but myriad constraints make it extremely difficult to do so. The subsequent discussions explore the feasibility of each branch line.

### **Feasibility of Branch Lines**

#### ***South of Market (SOM) Lines***

- Mission Street
- Howard Street

As mentioned earlier, the branch line top-of-rail depth is relatively shallow. The mainline from which it breaks out in this area is approximately 75 feet below the surface. Conflicts with deep foundations supporting the high-rises in this area are likely.

The deep fills and underlying mud (depths around 200 feet) run from the Embarcadero to the old coast line (which was near Montgomery Street to the west, Pacific Street to the north and Folsom Street to the south). Pile tips can be expected to reach 100 to 160 feet below the ground surface.

As a result tunneling operations will be riskier than those during the original BART construction. High value high-rise properties will require expensive underground easements as well as substantial underpinning efforts (for example, in the westbound (WB) path are the Embarcadero Center and Hyatt Regency located on the North Side of Market Street).

The WB branch line heading to SOM must dive under the mainline. It is expected that the dive will begin just after the breakout and is combined with the minimum horizontal curvature. A run of approximately 1000 feet with 3-4% grades is needed. It is expected that the earliest crossing will be at Main Street.

Both the WB and EB branches will impact, at varying degrees, the utilities within the streets. The vicinity of the breakout, where the most soil improvement is needed, will be the primary point of conflict. Access for soil stabilizing, improvement, and dewatering is the primary cause of disruption.

Eastbound branching does not cross under the mainline; however, profiles will need to match the WB branch line at a station along either of the corridors (perhaps in the vicinity of the Trans Bay Terminal or the Moscone Center). Again, property impacts are expected as EB branching will pass under the congested blocks on the south side of Market Street between Steuart and Main Streets (including the historic Southern Pacific Building at One Market, the Federal Reserve, etc.).

Plans to revamp the Transbay Terminal could drive the tunnel deeper. Various schemes are being studied and the environmental documentation is in progress. It is expected that the branch lines would cross the planned CALTRAIN and eventual High Speed Rail extensions at Fremont or Second Street.

At this time no specific recommendations can be made; however, it is likely that a deep tunnel (say with top-of-rail 120-ft below the surface) would avoid these conflicts.

### ***North of Market Lines***

- Geary Street

This study examined a potential Geary Street corridor that originated from the SOM corridors described in the previous section. This branch would have both the WB and EB lines crossing under the existing BART mainline, as well as the planned MUNI Third Street Line (a.k.a Central Subway).

Assuming the SOM branches are deep tunnels in order to avoid conflicts, it seems that these underground corridors could be avoided. In this area fills and muds transition to the original shore (dense sands). Building foundations are expected to be somewhat shallower, so direct conflicts are expected to be fewer than the within the SOM corridors.

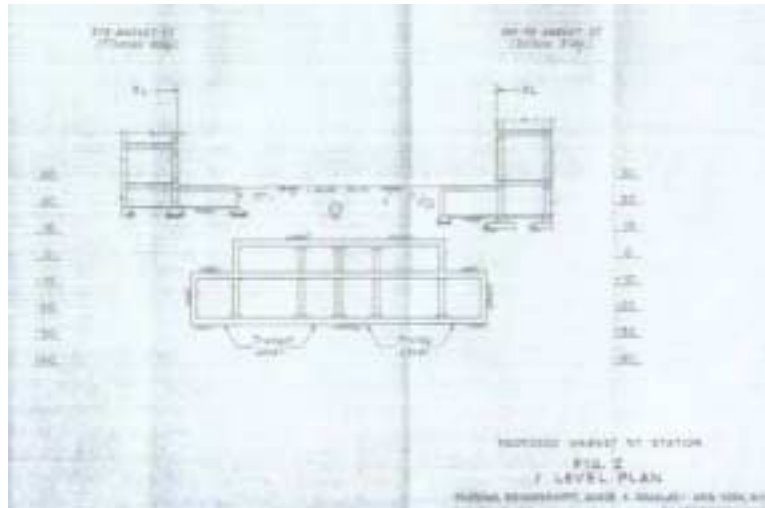
As a result of the greater depth of these branches, stations north of Market will be significantly deeper than the current BART lines.

### ***Market Street (Expanded)***

- Widen from 2 to 4 Tracks
- Take MUNI Level for BART (Add branch above)

A 4-track corridor was originally considered in the initial stages of BART planning (see Figure 7). This option had greater impacts on properties along Market Street (sidewalk vaults, foundations) as well as the utilities and surface street functions.

At the time, the resulting greater risks associated with the 4-track corridor were seen as potential “show stoppers”. Adding two flanking tracks today would cause even greater adverse impact on Market Street.



**FIGURE 7. ORIGINAL 4-TRACK MARKET STREET TUNNEL CONCEPT**

High-rise buildings with deep foundations into the fill and mud line each side of the underground BART/MUNI Lines. Sandwiched in between the sidewalk vaults and foundations of these new buildings are the utilities which were relocated to make room for BART/MUNI 30 years ago.

Connecting the new lines to the existing stations would be complicated, or even precluded, if the additional bores were made deeper than the current BART tunnels. Deep tunneling for both the WB and EB may facilitate a Geary Line (similar depth as SOM lines to avoid Central Subway) with a first (deep) station in the Union Square area.

A note on station modifications: the current outside walls of station boxes can only tolerate relatively small openings or cross passages. This is because these walls carry the MUNI platform and mezzanine and the street above.

### *Breaking Into and Replacing MUNI Level*

The scheme aims to get the existing BART mainline up to the MUNI level. The previously described on-shore breakout is still required. From the breakout a parallel climbing run will be constructed, once BART reaches the MUNI level BART will break back into the MUNI alignment between Fremont and Sansome Streets (see Figure 8).

Disruptions to Market Street would be significant. The parallel run would be shallower than the other alternatives and as a result, the impacts to adjacent properties would be greater than any of those previously discussed.

The break-in will be similar to the breakout and is expected to be located in between stations rather than at stations. Station modification to accommodate breakouts is not considered feasible since the outside walls of the station boxes can tolerate only minimal openings.

Break-ins and breakouts would, in effect, fill in the area in between stations, stiffening the tunnels and adversely impacting seismic performance.



**FIGURE 8. ALTERNATIVES FOR BREAKING INTO AND REPLACING MUNI**

### **Conclusions**

In general, the track geometry that results in good transit operations also happens to make it difficult to keep the tunnel within city streets. As a result the branch lines will conflict with many high-rise and historic properties resulting in very risky construction.

The following conclusions can be drawn:

1. Breakouts from and break-ins to the BART mainline are conceptually feasible but extremely disruptive to the surface, risky to buildings (high-rise and historic) and existing BART operations, and are extremely expensive.
2. An on-shore breakout would be more feasible than an offshore breakout at Yerba Buena Island. Though it creates more surface disruption, the risk to BART operations is less.
3. Breakouts introduce “hard points” that adversely impact seismic response. This is especially true of the YBI breakout.
4. Deep tunnels away from the breakouts (resulting top-of-rail 120 to 150 feet below grade) will have least impact on properties however these tunnels will require deep stations. Deep breakouts do not improve the situation since they result in greater surface disruption. The location of the most feasible breakout makes it nearly impossible to achieve the tunnel depth necessary to pass under high-rise foundations.

5. Expanding Market Street from two to four tracks, whether side-by-side or taking MUNI tracks is fraught with difficulties. Placing tracks on each side will allow more trains to run down Market Street but there will be nowhere to stop since station expansion is not practical. The taking of MUNI's Market Street tunnels is an even greater challenge since it is nearer to the surface and would create even more disruption. This option would result in the abandonment of the newly constructed MUNI Metro turnaround and the shutdown of the entire MUNI underground Market Street Corridor that connects the western reaches of the City to downtown and Pac Bell Park. As a result, MUNI would have to be relocated. The disruptions resulting from this alternative cause adverse impacts at too many levels to be politically viable.
6. A new Trans Bay tube/tunnel crossing is the most prudent and feasible alternative to increase BART capacity

History has shown that perceived low risk exposure paved the way to achieve the consensus needed to push the original BART construction forward. It seems logical that any expansion plan does the same.

**References:**

- 1: *Parsons Brinckerhoff the First 100 years, Benson Bobrick, Van Nostrand Reinhold, 1985.*
- 2: *San Francisco Bay Area Rapid Transit District Design Criteria (SFBARTD) – Volume I Civil, Section 3 Geometrics Rev1-02/01/9.*
- 3: *Report (To the SFBARTD) on Structural Concepts for the Construction of the Market Street Stations, by Parsons Brinckerhoff Quade & Douglas, December 1, 1964.*
- 4: *BART Tunnel Monitoring During MUNI Tunnel Construction, by Y. Hashash, B. Schmidt, L. Abramson (PBQ&D), June 1995.*
- 5: *Contract IB0031-B003 Plans – Trans Bay Line San Francisco Approach by PBTB, 24 Oct 1967.*

## Appendix 2B:

The following three alternatives assume construction of immersed tube tunnels under SF Bay for several of the alternative crossings. These alternatives were studied but rejected early in Phase I of this study due to fatal flaws or significant constraints, and are shown here as reference only.

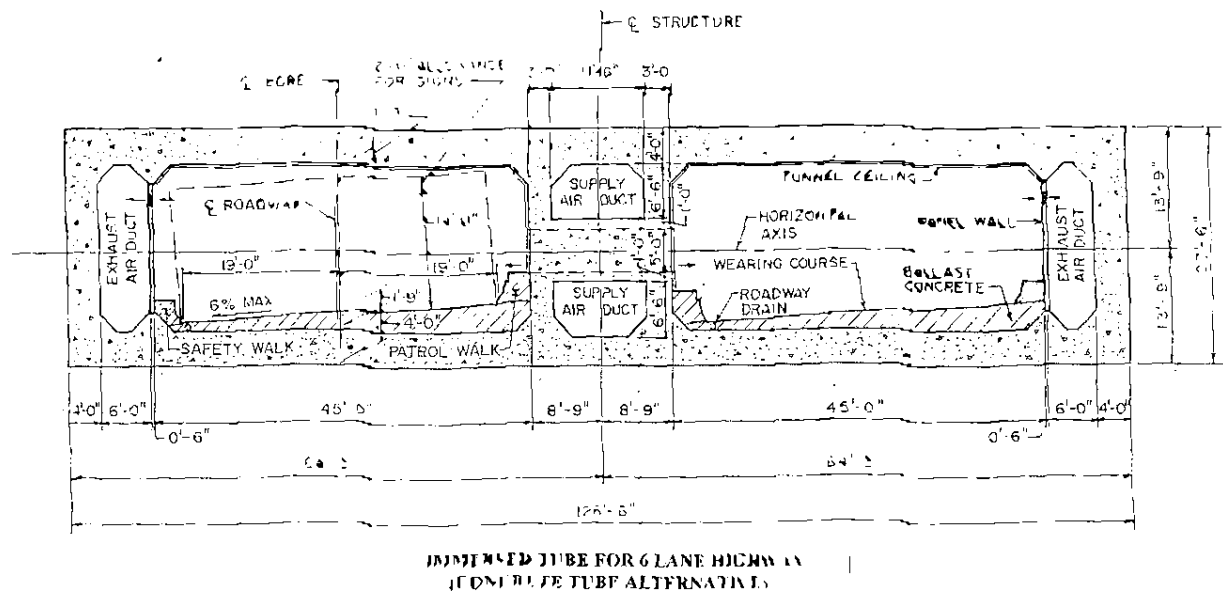
### Transbay Tube Alternative

This alternative includes two side-by-side lines of immersed tubes, which accommodate respectively East Bound (EB) & west Bound (WB) BART lines, and EB & WB Rail lines. The BART and Rail tubes would be placed in the same trench which would have to be dredged in the bottom of the Bay with 4:1 transverse slopes. The length of the immersed tubes vary from 350 ft. to 400 ft. and have binocular cross sections formed by external steel shell and two internal concrete liners.

### 380/580 Crossing Alternative (Tunnel, Island, Bridge)

This alternative considered six highway lanes (one tube) and 2 lanes of commuter rail (2nd tube) placed in the same trench on the bottom of the Bay. The binocular steel shell tubes are considered for the Commuter Rail. For the highway lanes the following two options should be considered:

**Option 1.** Reinforced concrete tubes with rectangular cross section. These tubes could be constructed in a quarry, which is connected with the Bay by a channel, or in a casting basin. The excavation for the adjacent cut -and-cover tunnel could utilize the casting basin.

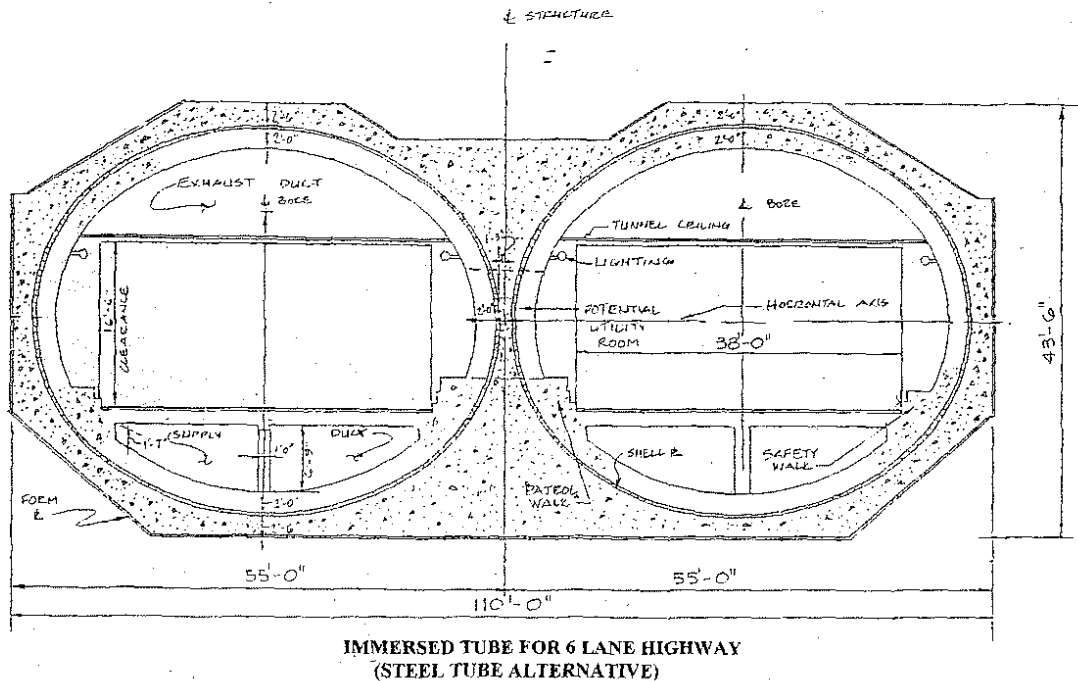


**Option 2.** Steel shell tubes with a bi-elliptical cross section.

Both options of this alternative require a transition section between the bridge and the immersed tubes. The transition assumed was a continuous underwater berm ("island"), 280 ft. wide, with a longitudinal slope at 3% (the maximum grade for the commuter rail). The length of this underwater berm was assumed 1660 ft. (assuming 40 ft. depth of the Bay and the bridge abutment at 10 ft. above the water). The immersed tubes can be placed only on the low portion of the berm. Where the draft of the tubes exceeds the depth of water

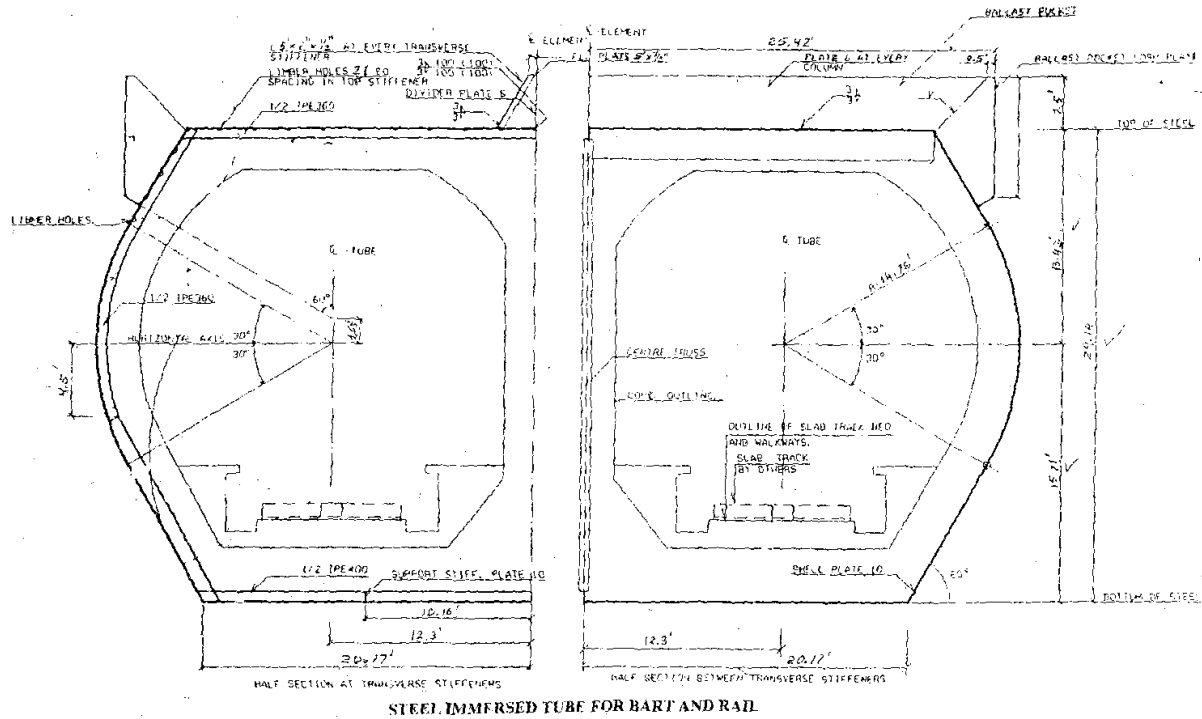
above the berm, a cofferdam must be constructed to provide construction of the cut-and-cover tunnels through the remainder of the berm, until the roadway or guideway daylight, and the bridge abutment is placed on the berm.

A cellular cofferdam was considered for this purpose. The steel bulkhead could be installed on the low end of the cut-and-cover tunnel. After construction of the abutment and cut-and-cover tunnels are completed, the cofferdam would be flooded, and the adjacent immersed tube would be connected to the cut-and-cover tunnels. The longitudinal cells of the cofferdam will be left in place to provide the stability of the soil berm and to protect the underwater tunnels from navigation traffic in the channel.



### Mid-Bay Tube Alternative

Binocular steel shell immersed tubes were considered to accommodate two tracks of BART. Their binocular cross-sections are formed by external steel shell and internal concrete liners.



STEEL IMMERSED TUBE FOR BART AND RAIL

## Appendix 5A:

Dumbarton Rail Bridge Basic Service Plan Cost Summary